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THESIS

**MODELING AND EVALUATING U.S. ARMY
SPECIAL OPERATIONS FORCES COMBAT
ATTRITION USING JANUS(A)**
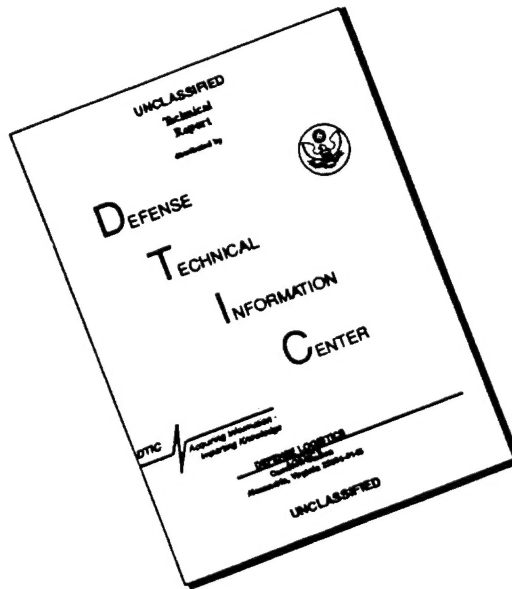
by

Gregory Ray Wilson

September 1995

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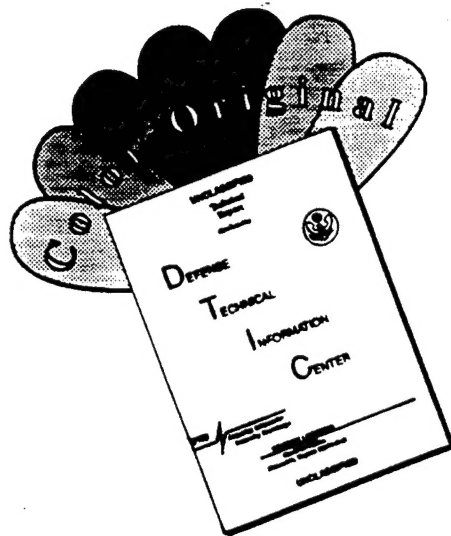
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This thesis examines the combat attrition of U.S. Army special operations forces (SOF). It develops a methodology for modeling SOF in Janus and calculating SOF attrition coefficients from high resolution combat model simulation results for use in Lanchester models of warfare. Selected missions involving SOF at the Joint Readiness Training Center (JRTC) are examined and likely force-on-force engagements between SOF and enemy forces are modeled in Janus. A statistical analysis of the simulation results is conducted and SOF attrition coefficients are calculated using the maximum-likelihood estimate of attrition coefficients technique. SOF casualty outcome trees are then developed for the scenarios modeled. Casualty outcome trees capture the overall results of the high resolution combat model and provide a framework for utilizing the attrition coefficients developed in this study. SOF casualty outcome trees could also be incorporated into aggregate combat models that resolve attrition using Lanchester models of warfare.

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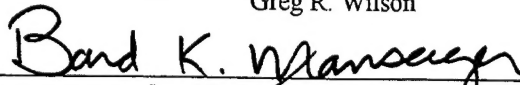
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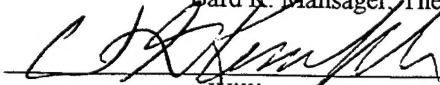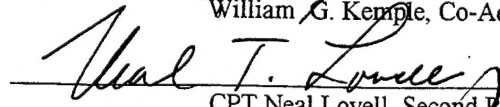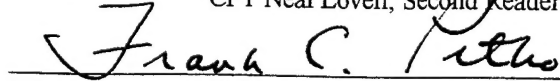**September 1995**

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ABSTRACT

This thesis examines the combat attrition of U.S. Army special operations forces (SOF). It develops a methodology for modeling SOF in Janus and calculating SOF attrition coefficients from high resolution combat model simulation results for use in Lanchester models of warfare. Selected missions involving SOF at the Joint Readiness Training Center (JRTC) are examined and likely force-on-force engagements between SOF and enemy forces are modeled in Janus. A statistical analysis of the simulation results is conducted and SOF attrition coefficients are calculated using the maximum-likelihood estimate of attrition coefficients technique. SOF casualty outcome trees are then developed for the scenarios modeled. Casualty outcome trees capture the overall results of the high resolution combat model and provide a framework for utilizing the attrition coefficients developed in this study. SOF casualty outcome trees could also be incorporated into aggregate combat models that resolve attrition using Lanchester models of warfare.

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EXECUTIVE SUMMARY

Special operations forces (SOF) are employed across the entire spectrum of conflict and serve as a strategic asset that cannot be built-up quickly or easily replaced when lost. Anticipating combat attrition to special operations forces is critical to USSOCOM in maintaining the proper force level to meet the expanding role of SOF in peacetime and in war. High resolution models such as Janus can be used as a tool to model and develop SOF attrition coefficients. Attrition coefficients developed from high resolution combat models can be used in aggregate combat models that resolve attrition using Lanchester equations.

This thesis examines the combat attrition of U.S. Army special operations forces. It develops a methodology for modeling SOF in Janus and calculating SOF attrition coefficients from high resolution combat model simulation results for use in Lanchester models of warfare. Selected missions involving SOF at the Joint Readiness Training Center (JRTC) are examined and likely force-on-force engagements between SOF and enemy forces are modeled in Janus. The special operations missions examined in this study are a direct action and a special reconnaissance mission.

The SOF scenarios modeled in this study are well suited for developing attrition coefficients using the MLE attrition coefficient technique. The scenarios modeled involve direct force-on-force engagements between special operations forces and enemy forces. The high resolution combat model used in this study produced a time series of casualties for each simulation replication. The short duration of the force-on-force engagements modeled make them ideal for producing MLE attrition coefficient estimates. Assessing the distribution pattern of MLEs provides added insight into the overall behavior of the attrition coefficient estimates.

The casualty outcome trees developed for the scenarios capture the overall pattern of SOF attrition resulting from the high resolution model simulation replications. The attrition coefficient estimates developed in this study are conditional in nature and rely on

probabilistic outcomes to determine when they are to be used in Lanchester equations to assess casualties. Casualty outcome trees are simple in structure and could easily be incorporated into aggregate combat models to resolve SOF attrition.

The diverse role of special operations forces in peacetime and in war makes it particularly difficult to predict all situations in which SOF casualties can occur in a conflict. Special operations forces are often employed in strategic economy of force operations where direct contact with enemy forces is unlikely. But, other SOF missions place soldiers in situations where direct contact with enemy forces is inherent or very probable. The direct action raid and special reconnaissance mission are clearly two situations in which force-on-force engagements with enemy forces are likely to occur. Larger scale operations like those conducted by ranger units are also well suited for modeling and developing attrition coefficients with high resolution models.

However, attrition to special operations forces is not always a process that can be modeled using Lanchester models of warfare. Deployment of SOF onto the modern non-linear battlefield will result in situations where massive casualties will be suffered by the force in a small instance of time. Examples of such situations are special operations (SO) aircraft that are shot down on infiltration/exfiltration and SO detachments that are compromised and engaged by enemy aircraft or artillery. These situations produce multiple casualties at the same time and are ill-suited for portrayal with Lanchester models. They are also likely to be SOF's greatest casualty threat in future conflict.

The attrition coefficients developed in this study are only as good as the high resolution model and the item level data input into the model. Accurately modeling special operation forces in a high resolution model is a difficult task. However, as high resolution models evolve, their ability to model special operations forces should continue to improve. Current efforts in modeling dismounted soldiers look promising and should enhance the efforts of future studies.

I. INTRODUCTION

A. GENERAL

The Joint Mission Analysis (JMA) is conducted by every component of the United States Special Operations Command (USSOCOM). The component JMA is compiled and analyzed at USSOCOM to determine future force requirements for all special operations forces (SOF). Currently, attrition factors for SOF do not exist. Therefore, at the conclusion of a conflict or a battle, the special operations forces are assumed to be at one hundred percent strength. This results in underestimating the size of the force needed to fight two simultaneous, or near simultaneous Major Regional Conflicts (MRCs). The U.S. Army calculated attrition factors for conventional forces based on Korean War and World War II data which are published in the Staff Officer's Guide FM 101-1-1/2 . The Concepts Analysis Agency (CAA) is considering conducting attrition analysis to update attrition factors for conventional forces, but has no plans to include SOF.

B. BACKGROUND

Special operations have proven to be an integral part of the combined arms team. When utilized properly they are invaluable assets to theater commanders throughout the entire spectrum of conflict. Many low resolution/aggregate combat models now incorporate the employment of special operations forces. Combat losses to special operations forces are unrealistic in the models because unique attrition factors for special operations (SO) are not adequately represented. A typical way of handling SOF attrition in low resolution models like TACWAR and Corps Battle Simulation (CBS) is as follows. Once a SOF unit is detected, it is attrited according to the model's standard light infantry attrition coefficients for aimed fire in the Lanchester calculations. In the Joint Theater Level Simulation (JTLS) model, SOF units are given a special attrition multiplier, applied when they are the killers in the Lanchester calculations [Ref. 1]. This is an effort to account for the fact that SOF units are specially trained and generally more effective than conventional units. However, the standard light infantry attrition coefficients used to assess casualties against the SOF fail to capture many critical synergisms of special

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operations forces and missions. As a result, the ability of aggregate models to accurately portray SOF attrition is limited. Current aggregate models provide USSOCOM with very little insight into realistic combat attrition of SOF units when evaluating war game results.

C. PROBLEM STATEMENT

Currently, attrition factors for Special Operations Forces do not exist. The intent of this thesis is develop a methodology for using a high resolution combat model to develop attrition factors for selected U.S. Army special operations missions.

D. SPECIAL OPERATIONS

1. Nature of Special Operations

Special operations are actions conducted by specially organized, trained, and equipped military and paramilitary forces to achieve military, political, economic or psychological objectives by nonconventional means in hostile, denied, or politically sensitive regions. Special operations missions are conducted during peace, conflict, and war, independently or in coordination with operations of conventional forces. [Ref. 2]

2. U.S. Army Special Operations Forces

U.S. Army special operation forces consist of Special Forces, Rangers, the Special Operations Aviation Regiment, Psychological Operations and Civil Affairs forces. The largest Army SOF component comprises the five active-duty special forces groups (SFGs). The major role of the special forces is to conduct direct action (DA) , special reconnaissance (SR), unconventional warfare (UW), and Foreign Internal Defense (FID) missions in support of theater commanders.

E. LITERATURE REVIEW

A detailed literature review was conducted, with the aid of the USSOCOM historian, to assess the feasibility of collecting historical data. The primary sources examined included after action reports (AARs) and operations reports from special operations units operating during World War II (WWII) and from the Korean War through Desert Storm. The security classification of many sources had recently been reduced to secret making them easier to access for research.

The WWII sources examined consisted of the Jedburgh operations into Europe, Ranger operations during the Normandy invasion, 1st Special Service operations in Italy and Alamo Scout operations in the Southwest Pacific. Sources documenting special operations conducted during the Korean and Vietnam War were limited, and detailed documentation of combat losses were not available. After action reviews (AARs) from more recent conflicts to include Desert Storm were also examined. Overall, the sources examined lacked a detailed breakdown of individual SOF operations and combat losses.

The following information was determined to be critical by the author and USSOCOM in evaluating SOF attrition: mission type, infiltration means, mission duration, number of personnel deployed on the mission, number of killed in action (KIA), number of wounded in action (WIA), environment and enemy activity in the area of operation. Less than fifty percent of this information was available in the documents examined. Due to the lack of detailed historical data, U.S. Army SOF attrition factors will be developed utilizing a high resolution combat model.

F. RESEARCH OBJECTIVE

The objective of this thesis is to develop a methodology for modeling selected U.S. Army SO missions in a high resolution combat model and calculating attrition factors from simulation results. The thesis will demonstrate this methodology by modeling selected U.S. Army special operations missions in a high resolution combat model. Mission scenarios to be modeled will be SO missions that are currently conducted at the Joint Readiness Training Center (JRTC). An experiment will be designed to execute the mission scenarios. The data produced by the simulation runs will be analyzed and statistical techniques will be utilized to develop attrition factors.

G. SCOPE AND LIMITATIONS

This research is unique in that there has been no other attempt to develop attrition factors for special operations forces utilizing the results from a high resolution combat model. The methodology will develop a general framework for determining likely or probable situations in which SOF forces could be involved in force-on-force engagements with enemy forces. The attrition factors developed in this study are unique to the

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scenarios and situations modeled. Numerous scenarios will need to be modeled and evaluated before a robust set of attrition factors can be developed for use in aggregate combat models. Current high resolution models were the greatest limitation to this study. Great care must be taken to insure that the capabilities of SOF are accurately portrayed in the high resolution model. However, as high resolution models continue to evolve, they will improve their ability to portray dismounted infantry and special operations forces. The model utilized in this study is Janus 4.0 which was selected because it is the current Army high resolution model used for analysis. It is also in use at both the United States Army Special Operations Command (USASOC) simulation center and the Joint Readiness Training Center. This study discusses some methods that can be utilized in Janus to better portray special operations forces. Finally, only two of the many missions conducted by SOF, direct action and special reconnaissance, were used for modeling purposes in this study.

II. MODELING SOF IN JANUS

A. GENERAL

U.S. Army special forces missions are currently being modeled at the SOF Simulation Center at Ft. Bragg, North Carolina using Janus. The focus of the modeling effort at the SOF Simulation Center is operational planning to prepare units for upcoming deployments and JRTC rotations. Conventional mechanized and light infantry operations are modeled to assist in the preparation of special forces soldiers to conduct mobile training teams (MTTs) and foreign internal defense (FID) missions. However, detailed analysis of simulation results has not been conducted.

Decision makers will only use the results of a model if they believe the model can accurately portray the soldiers and weapons involved in the scenario under representative terrain and environmental conditions. The first half of this chapter will focus on the suitability of Janus to model special forces operations. It will assess how well Janus represents the individual dismounted soldier's ability to shoot and move. The second half of the chapter will address the limitations of modeling special forces in high resolution models. Lastly, techniques utilized to account for some unique aspects of special operations forces and missions are discussed.

B. SUITABILITY OF JANUS

1. General Description

Janus is the primary high resolution combat simulation model for brigade size and below operations approved by the U.S. Army. It can be used interactively or non-interactively. Interactive play, using a man-in-the-loop, replicates realistic battlefield conditions because as the enemy's activity develops, reactive decisions can be made. However, adding a man-in-the-loop creates more variability and may introduce bias.

Janus uses line of sight (LOS) algorithms and the U.S. Army's Night Vision and Electro-Optical Laboratories (NVEOL) model to detect targets. A target must be within LOS and weapon range for an engagement to occur. Engagement outcomes are stochastically determined based on probability of hit (P_h) and probability of kill (P_k) data.

Outcomes are binomial, either a suppression, which is a miss, or a kill. Suppression prevents the weapon system that is receiving fire from returning fire for a user specified length of time. When kills occur in Janus they are all catastrophic. The P_h and P_k data for the weapons used in the scenarios were unclassified data provided by TRAC. Parameters from other sources, such as technical and field manuals, were also utilized. Examples of these parameters are round velocity, basic load of ammunition, time required to reload the weapon, number of trigger pulls before reload, and number of rounds per trigger pull. A system can be as simple as a soldier with a semi-automatic weapon, or as complex as a platoon of tanks, each having multiple weapons. Each system is represented with a graphical symbol regardless of its complexity level.

Terrain in Janus is normally one hundred meter resolution. However, Janus has the capability to utilize terrain with increased resolution. Elevation, vegetation, water, urban areas, and cultural features are represented by data from the Defense Mapping Agency (DMA) and Waterways Experimentation System (WES). The JRTC scenarios are modeled using the Ft. Polk terrain database which was recently updated. The vegetation, water, urban areas, and primary/secondary roads are very accurately represented. Movement rates of vehicles and soldiers are adjusted to account for the effects of differing terrain. Dense vegetation and steep slopes slow movement rates. Janus also uses meteorological data, which the detection algorithms incorporate to either enhance or hinder detection capabilities. Night representation has been added to Janus, which affects the detection capabilities of a system's sensors. The terrain, weather, day and night capabilities increase the realistic representation of the SOF mission scenarios.

2. Individual Dismounted Soldier

Each soldier can be individually modeled as a system in Janus. This provides the capability for each soldier's location and movement routes to be planned separately. Each soldier/system can be assigned the individual weapons that would be employed during the mission. Soldiers employing more than one weapon can be assigned ranges in which to use their primary and alternate weapons. Priorities of fire can be assigned so that soldiers will engage targets according to a designated precedence. Each soldier can also be

assigned primary and alternate sensors that are used to acquire targets. Ammunition basic loads, re-load times and rounds per trigger pull can also be pre-designed. Modeling individual soldiers works well for small unit operations. However, movement planning and control becomes unwieldy for unit operations larger than platoon level.

3. Movement

Special forces soldiers use terrain features and vegetation to mask their movement in enemy territory. Movement of individual soldiers in Janus can be planned to take advantage of both terrain relief and vegetation. The line-of-sight (LOS) feature in Janus can be used to plan routes that minimize the chance of enemy detection around the target area. Routes are designated by using movement nodes. Movement nodes can be timed to assist in coordinating synchronized movement events, such as assaults. A sprint function is available which allows soldiers to move at maximum speed. However, soldiers moving in the sprint mode remain fully exposed during the duration of the movement.

During movement Janus does not distinguish between a soldier crouching, high crawling or low crawling. This is not a problem if LOS does not exist between the soldier and enemy forces. However, if LOS exists the soldier is modeled as if he is fully exposed which increases the probability of detection. This can lead to abnormally high detection rates for special forces soldiers moving into overwatch or hide positions around a target. Techniques to counter this effect will be discussed in Part D.

4. Shooting

Soldiers can be given a pop-up status in Janus that places them in a defilade status when they are not moving. This effectively simulates a soldier stopping in a covered position which affords some protection from enemy observation and engagement. The soldier's sensors continue to scan its field of view for potential targets and will automatically move from a defilade status to a partial defilade status to engage targets. Soldiers can also be placed in hold fire status if they are not to engage detected enemy forces.

Each soldier can be assigned an individual field of view which assigns a sector of responsibility to the soldier's sensors. If LOS exists and the target is detected it goes onto

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the soldier's target list and is assigned a priority. The LOS feature can be used to check individual firing positions to insure that LOS exists and that the target area is within the soldier's primary weapons range.

5. Night Operations

Night operations can be modeled in Janus 4.0. A separate database must be constructed to accurately model night operations. The night database should include probability of hit tables that have been adjusted for night firing. Night sensors data for night scopes and night vision devices was obtained from TRAC Operations and Analysis Center, Data Development Division at Ft. Leavenworth, KS. The sensor data, in the form of Mean Resolvable Cycles (MRC) curves, is considered classified data and must be perturbed before it can be run on unsecured computing platforms. The MRC curves for night sensors used in this study were perturbed slightly, using guidance from TRAC, to allow the study to be conducted on unsecure computing platforms. The MRC curves are broken down into numerous illumination conditions. The night illumination condition utilized in this study is quarter moon illumination.

C. LIMITATIONS

High resolution models are continuously improving their ability to portray the modern battlefield. However, certain aspects of combat will never be accurately captured by mathematical models and simulations. Initial simulation runs revealed many of the limitations noted below. The following limitations area not unique to Janus, but are prevalent in most high resolution combat models. Techniques used to adjust for some of the more critical shortcomings are discussed in Part D.

1. Battle Field Sound

Special forces soldiers use stealth while moving to prevent detection. Targets are often detected by sound alone, particularly at night. Janus does not have a sound sensing algorithm to distinguish the different noise levels between a vehicle moving along a road or a soldier creeping through the woods. Improvements in this area are being studied and may be implemented in the future.

2. Element of Surprise

Special forces operations are carefully planned and executed operations that often rely on the element of surprise to provide a distinct advantage during mission execution. It is difficult to account for the element of surprise in Janus. Enemy soldiers are assigned fields of view and continuously scan their sectors of responsibility. However, the field of view of soldiers can be manipulated to reflect a forces' level of alertness during a particular scenario.

3. Training Levels

Janus does not have an algorithm that distinguishes different training levels between opposing forces. Special forces soldiers are highly trained professional soldiers who are accustomed to operating independently behind enemy lines. They possess highly specialized skills and enhanced basic soldier skills that make them an extremely lethal force. Moreover, motivation and desire to succeed have been the hallmarks of the American soldier throughout history. These intrinsic qualities are difficult to captured in current combat models.

4. Reconnaissance

During special forces mission planning, intelligence assets often provide detailed assessments of the target area. Once special forces units arrive in the target area, a detailed ground reconnaissance is normally conducted to fix the location of the target and potential threats to the operation. Currently it is difficult for Janus and other high resolution combat models to portray the advantages afforded to a force that has detailed accurate intelligence prior to the conduct of a operation. Research is being conducted in this area and improvements may be made in the future.

5. Human Factors

Like most combat models, Janus does not have algorithms that can predict how humans will react in combat situations. Fatigue levels from continuous operations can often impair a soldier's judgment. Individual soldier loads can have a great impact on movement speeds and the duration of movement. A soldier's level of alertness is affected by stress, amount of sleep and numerous other factors. It continuously changes

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throughout the course of a operation. Soldiers often become complacent when they are in what they perceive as safe areas while senses are often heightened during actual combat.

D. SOF UNIQUE MODEL ADJUSTMENTS

The following model parameter adjustments were determined to be important for a more accurate portrayal of special operation forces in Janus. Adjustments were based on operational experience and were determined to be reasonable by the USSOCOM simulation center.

1. Movement

Test simulation runs revealed that special forces soldiers moving into overwatch or hide positions around the target were detected by enemy forces at an unreasonably high rate. Soldiers moving into these positions normally crawl to minimize their chance of detection. The minimum detection dimension is equal to the smallest of the system's dimensions in meters. This parameter is used in the Janus detection algorithm to determine if a potential target is acquired. A standard dismounted soldier moving in a crouched position has a minimum detection dimension of 0.2 meters. For soldiers moving into overwatch or hide positions this parameter was iteratively reduced until they could successfully move into position undetected. The value of the minimum detection dimension was reduced to 0.1 meters (1/2 original value) to account for their movement posture around the objective area. This change resulted in detection rates that were clearly more realistic and allowed the SO forces to gain the element of surprise.

2. Reconnaissance

Ground reconnaissance by special forces prior to the execution of actions on the objective is conducted to locate the target and potential threats to the operation. Determining the location of all enemy forces on the target is a critical part of the reconnaissance. When supporting or overwatch elements move into position around the target, they will in effect have already detected the enemy forces. A plausible way to account for this in Janus is to increase the minimum detection dimension of enemy forces on the objective. The minimum detection dimension of enemy was iteratively increased until the SOF soldiers in supporting positions could acquire enemy soldiers on the

objective. The value of the minimum detection dimension was increased from 0.2 to 0.5 meters to account for knowledge of the enemy's location gained through ground reconnaissance.

3. Training Level

Attempting to account for the superior training and lethality of special forces in Janus is a difficult task. Adjusting the probability of hit given shot ($P_{h|s}$) tables for weapons systems used in the scenario is a possible course of action. The $P_{h|s}$ tables for friendly forces are based on the marksmanship skills of conventional U.S. soldiers. Threat forces $P_{h|s}$ tables are for forces assumed to be at the same marksmanship level as Soviet military forces.

Marksmanship skills possessed by special operations forces are clearly superior to those of conventional forces. However, an analysis to quantify the level of increase that is justified has not been conducted. This study will increase the $P_{h|s}$ tables for SOF forces by ten percent which is likely to be a conservative estimate. This will help to reflect the increased lethality of SOF in the scenarios. Special operations forces are often employed against forces that may not be at same marksmanship skill level as Soviet forces. Adjustments up or down to enemy $P_{h|s}$ tables may be justified depending on the presumed marksmanship skill level of the threat forces modeled in the scenario. These adjustments are very subjective in nature and should be made with great care. This study will make no adjustments to the enemy $P_{h|s}$ tables.

III. METHODOLOGY

A. GENERAL

The following methodology was used for calculating SOF attrition factors. The methodology uses the results from a high resolution combat model to calculate attrition coefficients for selected special operations missions. This study uses SO mission scenarios currently being conducted at JRTC. The structure of the methodology incorporates a multi-step process that is diagrammed below.

Figure 3-1. Methodology

The methodology begins with the modeling of special operations forces as discussed in Chapter II. A scenario combat attrition analysis was then conducted to determine the force-on-force engagements between special forces units and enemy forces that are most likely to occur during the particular scenarios. The force-on-force engagements identified in the attrition analysis are then modeled in Janus. Finally, a statistical analysis is conducted and attrition coefficients are developed from the simulation results utilizing the maximum-likelihood estimation (MLE) approach. The baseline threat in the scenarios is modeled after the opposing force (OPFOR) employed at JRTC. The number of enemy forces and illumination conditions is varied in the scenarios to provide robustness.

The remainder of this chapter will be devoted to examining the scenarios and forces modeled, conducting the scenario attrition analysis, describing the MLE attrition coefficient technique and outlining the experiment.

B. SCENARIOS

The scenarios modeled are special forces missions currently conducted at the Joint Readiness Training Center (JRTC) at Ft. Polk Louisiana. JRTC is the premier training and evaluation center in the Army for light infantry and special operations forces. The role of JRTC is to prepare forces to conduct their wartime missions in a joint service environment. The overall scenario is geared toward contingency operations in a low intensity conflict. Typically, U.S. Army special forces units are deployed prior to hostilities into the mythical country of Cortina to conduct special reconnaissance, foreign internal defense, and direct action missions in support of the conventional forces commander. Operations are conducted just as they would happen in a real conflict, with a dedicated OPFOR that is modeled after a low intensity threat force. Observer controllers accompany all friendly units and provide detailed after action reviews upon the completion of operations.

1. Special Forces Missions

The primary missions conducted by Army special forces units are direct action, special reconnaissance, unconventional warfare, foreign internal defense, civil affairs, psychological operations, counter terrorism, search and rescue, and humanitarian assistance operations. This study will model selected parts of direct action and special reconnaissance scenarios conducted during JRTC rotation 95-3.

a. Direct Action

Direct action (DA) operations are short-duration strike or other small-scale offensive actions by SOF to seize, destroy, or inflict damage on a specific target or to destroy, capture, or recover designated personnel or property. Direct action operations include raids or ambushes, seizure of key facilities, interdiction of major lines of communication, recovery of sensitive items of equipment, abduction of selected enemy

personnel, liberation of captured personnel, support of deception operations, and show-of-force operations [Ref. 3].

The direct action mission modeled in this study involves a raid on a key enemy communications site to recover a critical component of a radar system. The component is a digital data down-link/up-link cipher control module that enhances the enemies ability to coordinate air-defense assets. The control module has not been placed into operation yet, and represents an significant threat to U.S. aircraft after employment. The target is believed to be occupied by a small armed force and two technical advisors. The mission is to recover the cipher control module and destroy any remaining equipment.

b. Special Reconnaissance

Special reconnaissance (SR) is an activity conducted by SOF to obtain or verify information concerning enemy activity and/or secure data of meteorological, hydrographic, or geographic characteristics of an area. This is accomplished by using small teams, with specialized communications equipment, that have a minimal chance of detection, to collect and report information in support of essential elements of information and other intelligence requirements [Ref. 3]. Special reconnaissance missions conducted at JRTC include the observation of key enemy resupply caches, avenues of approach and other named areas of interest (NAI).

2. Friendly Forces

The U.S. Army special forces unit modeled in the scenarios is the Special Forces Operational Detachment (SFOD). The SFOD consists of two officers and ten enlisted soldiers. The soldiers on the detachment are highly trained in their specialty MOS and receive cross-training in all critical detachment skills. Below is an organizational diagram of the detachment.
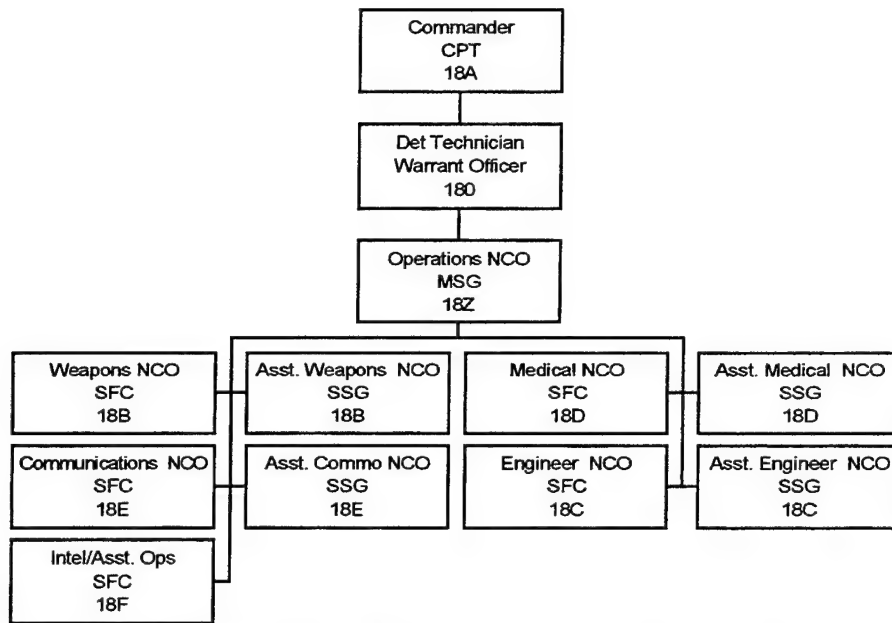
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                    │      MSG        │
                    │      18Z        │
                    └─────────────────┘
```


Figure 3-2.   SFOD Organizational Diagram

SFODs can deploy into the operational area by air, land or sea. They are capable of moving over rugged terrain in any weather conditions, day or night. Their small size and capability of conducting operations in a stealthy manner makes SFODs difficult to detect and defend against. The table below displays the standard individual weapons and sensors that were used to modeled the SFOD in the Janus simulations.   The SFOD's weapons remain fixed in all the scenarios modeled.   The weapons and sensors were modeled from information obtained in the <u>Army Special Forces Data Reference Guide</u> .

Position	Weapons	Day Sensors	Night Sensors	
Detachment Commander	M16/9mm	eyes/binos	AN/PVS-7	AN/PVS-5
Detachment Technician	M16/9mm	eyes/binos	AN/PVS-7	AN/PVS-5
Operations Sergeant	M16/9mm	eyes/binos	AN/PVS-7	AN/PVS-5
Intelligence Sergeant	M16/9mm	eyes/binos	AN/PVS-7	AN/PVS-5
Weapons Sergeant	M60/9mm	eyes/binos	AN/PVS-7	AN/PVS-5
Assistant Weapon Sgt	M203/9mm	eyes/binos	AN/PVS-7	AN/PVS-5
Medical Sergeant	M16/9mm	eyes/binos	AN/PVS-7	AN/PVS-5
Commo Sergeant	M16/9mm	eyes/binos	AN/PVS-7	AN/PVS-5
Engineer Sergeant	M249/9mm	eyes/binos	AN/PVS-7	AN/PVS-5
Assistant Engineer Sgt	M203/9mm	eyes/binos	AN/PVS-7	AN/PVS-5

Table 3-1. SFOD Weapons and Sensors

3. Enemy Forces

Enemy forces portrayed in the scenarios are the People's Revolutionary Armed Forces of Atlantica. The enemy force is modeled after a third world military force that is flexing its muscles in an attempt to intimidate a country with close ties to the United States. The enemy's posture was determined from SOF Combat Instructions 95-3 [Ref. 8]. The instructions outline the number of enemy personnel on the targets and their behavior. The enemy forces located on targets are lightly armed and only strong enough to provide limited local security. They do not actively patrol around the targets and are thought to maintain a platoon size reaction force that can respond to most areas within thirty minutes. The enemy soldiers in the scenarios modeled have the weapons and sensors displayed in the table below.

Position	Weapon	Day Sensors	Night Sensors
Riflemen	AK-74	eyes	eyes

Table 3-2. Enemy Weapons and Sensors

This study also develops attrition factors using variations to the baseline enemy force by altering the enemy force size.

C. SCENARIO COMBAT ATTRITION ANALYSIS

Combat attrition analysis of a scenario is done to determine probable or likely situations that could result in force-on-force engagements between the SFOD and enemy forces. This is a subjective evaluation that examines the scenarios and determines the most probable situations in which the SFOD could incur combat casualties. Attrition analysis cannot predict all the situations in which a SFOD could come into contact with enemy forces. However, a careful examination of the scenario, focusing on the terrain and enemy activity, can provide insight into the most probable situations in which SFOD and enemy encounters could occur. This section will first break down a typical SFOD mission into phases to give the reader a better understanding of the overall structure of a SO mission. Each scenario was then examined to determine the force-on-force engagements to be modeled in Janus. JRTC observer controllers (OCs) were interviewed and provided

critical insight for the selection of probable force-on-force engagements. Their experience proved invaluable in determining the situations modeled in this study.

1. Mission Phases

Following is a breakdown of a SFOD mission into its major phases. Most SO missions conducted into denied areas can be broken down into these three major phases.

a. Infiltration Phase

Infiltration consists of the initial phase of the operation to insert the special operations forces into the denied area. Special operations aircraft, normally employed to insert the SFODs, are specially designed to penetrate enemy air space undetected. SFODs can conduct infiltration into denied areas by air, land, or sea.

b. Mission Duration

Mission duration can normally be broken down into additional sub-phases of the operation. These generally consist of movement in a denied area, to and from the target or objective, and actions on the objective. Listed below are the sub-phases of mission duration in a denied area.

- Movement to the target area: The movement from the point of infiltration to the target.
- Actions on the objective: Actions conducted on or in the vicinity of the target. Normally the most important phase of the mission and the phase where special operations forces are most vulnerable to combat losses.
- Movement to the extraction point: Movement from the target area to the location were the force is to be extracted.

c. Exfiltration Phase

Exfiltration consists of the final phase of the operation, utilized to extract the special operations forces from the denied area. Exfiltration is also conducted by air, land, or sea.

The operational phases provide the general framework for the attrition analysis. The results of the attrition analysis and key assumptions used in modeling the engagements are discussed below.

2. Direct Action Mission

The attrition analysis conducted on the direct action mission to seize the cipher control module resulted in two likely situations involving force-on-force engagements to be modeled in Janus. The situations involve the actual actions on the objective phase of the operation and possibility of chance contact with the enemy.

a. Actions on the Objective

Clearly, the SFOD must actually send forces onto the objective to seize the cipher control module. This places the SFOD in direct contact with enemy forces on the target during the actions on the operation phase.

b. Chance Contact

The SFOD could be detected during any phase of the operation. Detection would likely result in enemy contact. The most probable situation that results from the detection of the SFOD by enemy forces is chance contact. Chance contact may result in an engagement with enemy forces in which the SFOD will immediately attempt to break contact and move to a safe area or extraction point. After successfully breaking contact, the commander will then determine whether or not to continue the mission, based on the degree of compromise. Detection often results in an aggressive attempt by enemy forces to find and capture the SFOD. Having lost the element of surprise, the SFOD will likely be forced to abort the mission.

3. Special Reconnaissance

The nature of a SR mission made the attrition analysis quite simple. The object of SR is to remain undetected throughout all phases of the operation to gather and report the information required of the mission. Since there is no planned contact with enemy forces during the actions on the objective phase, the only situation that could result in attrition to the SFOD is chance contact.

4. Assumptions

The following assumptions highlight some of the results from the attrition analysis and conversations with observer controllers at JRTC. The assumptions also simplify the modeling of the force-on-force engagements in Janus.

a. Infiltration and Exfiltration

The enemy forces in the scenario do not currently have a significant air defense network that can threaten low flying special operations aircraft. Therefore, situations involving attrition during the infiltration and exfiltration phases of the operation will not be modeled in this study.

b. Reinforcements

The reaction force in the scenario can reinforce the objective area in approximately thirty minutes. However, the SFOD's ability to strike quickly will enable it to conduct the operation and leave the objective before it can be reinforced by a reaction force. This assumption was confirmed by OCs and by initial scenario test runs in Janus. The actions on the objective phase modeled for the direct action scenario will not allow for the reinforcement of enemy forces during the simulation.

c. Chance Contact

The terrain and vegetation at JRTC provide excellent cover and concealment for SFODs during all phases of movement. The SFODs can normally plan routes to and from the objective that take advantage of both the terrain, and vegetation, to minimize the chance of detection by enemy forces. The enemy forces in the scenario do not have the time or resources to conduct aggressive patrolling operations. When enemy patrolling is conducted, it is restricted to major roads and trails. Thus, chance contact between a SFOD and the enemy is only likely to occur when the SFOD negotiates a major danger area in route to, or in return from the objective. Danger areas are defined as major roads or open areas adjacent to trails or roads. Danger areas can often be bypassed during movement, however situations do occur were a SFOD must negotiate danger areas.

D. MAXIMUM-LIKELIHOOD ESTIMATES OF ATTRITION COEFFICIENTS

1. General

The attrition coefficients produced by the simulation results in this study are situation dependent attrition coefficients. They can be utilized in aggregate models that use situation dependent attrition coefficients in Lanchester equations to resolve attrition. The attrition coefficients developed in this study are limited to the situations identified and modeled in this study. However, follow on work in this area may provide a richer set of situationally dependent attrition factors for special forces operations.

The attrition factors specifically apply to the Lanchester equations for aimed fire. The Lanchester attrition model for aimed fire defines the change in a force's size during a battle, with respect to time, as a function of the attrition coefficient multiplied by the size of the opposing force. The Lanchester attrition model for aimed fire, in mathematical terms are as follows:

$$\frac{dy}{dt} = -bx \qquad\qquad \frac{dx}{dt} = -ay \qquad\qquad (1)$$

The maximum-likelihood estimation approach produces estimates of a and b, based on the situations modeled, which can used in Lanchester equations.

2. Maximum Likelihood Estimate Formula

The maximum-likelihood estimation (MLE) approach was utilized to calculate the force-on-force engagement attrition coefficients from the simulation results. The MLE approach is a fitted parameter model which takes a time series of casualty times and computes the maximum-likelihood estimate of the mean time between casualties. In developing the MLE approach, the battle casualties for the two opposing forces are treated as a continuous-time Markov-chains, and as a result the casualty streams are merely two superimposed POISSON processes. The MLE approach develops statistical estimates of the attrition coefficients, denoted as $\hat{a}$ and $\hat{b}$, which are also maximum-likelihood estimators of the POISSON parameter. The MLE model captures many of the synergistic effects involved in the combat simulation such as fire and maneuver and the complementary effects of various weapon mixes. The model assumes that a Lanchester

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process is occurring and incorporates all assumptions that are implicit in the particular high resolution combat model being utilized. The attrition coefficient estimates is a function of the total casualties suffered by the particular force, x or y, divided by the summation of the total enemy firing minutes. The following formula are used to calculate the attrition coefficient estimates. [Ref. 4]

$$\hat{b} = \frac{c_T^y}{\sum_{k=1}^{K} m_{k-1}(t_k - t_{k-1})} \qquad\qquad \hat{a} = \frac{c_T^x}{\sum_{k=1}^{K} n_{k-1}(t_k - t_{k-1})} \qquad (2)$$

Equation Terms:

c_T^x = *the total casualties to side X*

c_T^y = *the total casualties to side Y*

t_k = *time until the occurance of the kth casualty*

m_k = *size of the X force after the kth casualty*

n_k = *size of the Y force after the kth casualty*

$k = 1, 2, .., K$

Dimensional analysis of the above attrition estimators indicates that :

$$\hat{a} = \frac{total\ X\ casualties}{total\ enemy\ firer\ time\ units\ against\ X}$$

Examining the dimensionally of the Lanchester Square Law attrition coefficient :

$$a = \frac{number\ of\ X\ casualties}{(Y\ firers) \times (time)}$$

Comparing the two it is easy to see that the MLE is a true estimate for the Lanchester attrition coefficient [Ref. 5]. The Coroner's Report in Janus provides a detailed record of casualty times for each simulation run. The formulas above are easily incorporated into a spreadsheet to simplify attrition factor calculations.

E. EXPERIMENT

The experiment is designed to provided insight into how various critical factors influence the combat attrition suffered by the SFOD. Janus provides the ability to assess scenarios under numerous conditions and parameter variations. Examples of such variables are tactical plans, terrain, weapon mixes, enemy force size, and other battlefield conditions. Clearly the enemy strength will have a direct impact on the attrition suffered by the SFOD during a force-on-force engagement. Varying the enemy force size can provide valuable insight into the range of attrition suffered by SO forces facing different enemy strengths. Technology advantages such as night vision devices and night sights can also have an impact on the outcome of a engagements and the combat attrition suffered by opposing forces. The number of parameters and conditions varied in this study will be limited largely by time. For the purpose of this study, one tactical plan will be developed for each force-on-force engagement modeled. The tactical plans are executed under day and night illumination conditions against different enemy force sizes. The conduct of each force-on-force engagement is detailed below.

1. Direct Action Scenario

The DA scenario was planned by three special forces officers, each having had a minimum of eighteen months as a SFOD commander. The officers were given a tutorial on using Janus to familiarize them with the model's basic functions and characteristics. They were then given a brief scenario description, mission statement, the target location and the suspected enemy strength. A ground reconnaissance of the objective was conducted using the LOS feature in Janus. The officers then developed the tactical plan for the actions on the objective, to include SFOD organization, movement routes, and weapons locations.

The SFOD was organized into support and assault elements. The SFOD approached the objective utilizing a draw to conceal their movement (see Appendix A). The support element established two positions, one to the north and the other to the east of the objective. The support element, armed with an M60 machine-gun, a squad automatic weapon (SAW) and an M203 grenade launcher, established positions providing

LOS and supporting fire on the objective. Support positions also isolated the objective by covering the major avenues of approach into the radar site. The assault force, consisting of seven soldiers, approached the objective from the northeast wood line. The support force provided covering fire while the assault force moved across the objective to the west road on the objective. Once the assault force reached the limit of advance, the west road, the simulation was terminated.

The tactical plan was then executed under both day and night illumination conditions, against four different enemy threat packages. The enemy threat packages for the DA scenario vary the enemy force size from the baseline of three soldiers, to six, twelve and twenty-four enemy soldiers, respectively. The enemy forces were deployed in static positions in a perimeter around the radar site in all scenarios.

The DA scenario simulation plan includes one tactical plan, four enemy threat packages and day/night illumination conditions. This results in eight different scenario combinations. Each of the eight scenarios was further replicated twenty times varying the random number seed to change the probabilistic nature of the models results.

2. Chance Contact Scenario

The chance contact scenario models a break in contact between the SFOD and the enemy force. The SFOD is crossing a danger area (large open area) and an unknown enemy force is patrolling in the area. The SFOD establishes overwatch positions and moves across the open area. While negotiating the danger area a meeting engagement occurs with the enemy force in which a break in contact ensues (see Appendix A). For the purpose of this study chance contact can result in one of two different break in contact situations. If enemy forces detect the SFOD while exposed in the open area the SFOD will utilize a standard battle drill used by ranger patrols and special forces detachments to break contact [Ref. 6]. Once under fire, the SFOD will use successive bounds, with one element always providing suppressive fires to cover the moving element, to break contact with the enemy force. The enemy force will conduct similar movement techniques as it attempts to close on the SFOD. Once the SFOD successfully moves back into the wood line and is no longer exposed to enemy fire the simulation is terminated. However, if the

SFOD detects the enemy force first it will attempt to avoid contact and move into the cover of the wood line.

The break in contact will be modeled under day and night illumination conditions against four enemy force packages. The enemy force strength is varied from a baseline force of three, six, twelve and twenty-four enemy respectively. The conduct of the chance contact scenario includes one tactical plan, four threat packages, under day and night illumination conditions. This also results in eight separate scenario combinations. Again, each scenario will further be replicated twenty times changing the random number seed.

IV. ANALYSIS

A. GENERAL

The overall focus of this analysis is to develop situation dependent SOF attrition coefficient estimates from the Janus simulation results. The analysis first examines the overall casualty trends from the force-on-force engagements modeled. Casualty trends provide insight into how to best model the force-on-force engagements and calculate the attrition coefficient MLEs. After examining the casualty trends, attrition coefficient MLEs are calculated for all scenario replications. When possible attrition coefficient estimates fit to theoretical probability distributions capture the general behavior of the attrition coefficient estimates. Finally, a casualty outcome tree is developed for each force-on-force engagement. Casualty outcome trees provide a model for assessing SFOD casualties utilizing Lanchester equations and the attrition coefficient estimates developed in this study. While this study develops some attrition coefficients for the enemy forces modeled in the scenarios, the focus of the analysis is the combat attrition to the special forces detachment.

B. CASUALTY TRENDS

Basic casualty trends for the force-on-force engagements can be observed by examining boxplots of casualties suffered by the special forces detachment (SFOD) in each of the scenarios modeled. The boxplots provide a quick impression of certain prominent features of the casualty distributions [Ref. 10]. SFOD casualties are examined with respect to changes in the enemy force size and illumination conditions. Casualty comparisons are also made between the direct action and the break contact force-on-force engagement.

1. Enemy Force Size

a. Direct Action Raid force-on-force engagement

The boxplots for the direct action raid clearly show an increase in SFOD casualties as the size of the enemy force size on the objective increases for both the day and night scenarios. The detachment's average number of casualties during the day

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scenario increases from .35 to .5, 1.9, and 7 respectively. The median number of casualties, the center or location of the distribution, is zero against three and six enemy forces. The median number of casualties increases to two and seven against twelve and twenty-four enemy forces respectively (see Figure 4-1). There are outside values, observations falling beyond the adjacent values, in the casualty distribution against three, six and twelve enemy. These values are revealed in the plots because the majority of the simulation replications against these enemy force sizes resulted in little to no SFOD casualties. The largest increase in detachment casualties clearly occurs when the enemy force size increases from twelve to twenty-four soldiers.
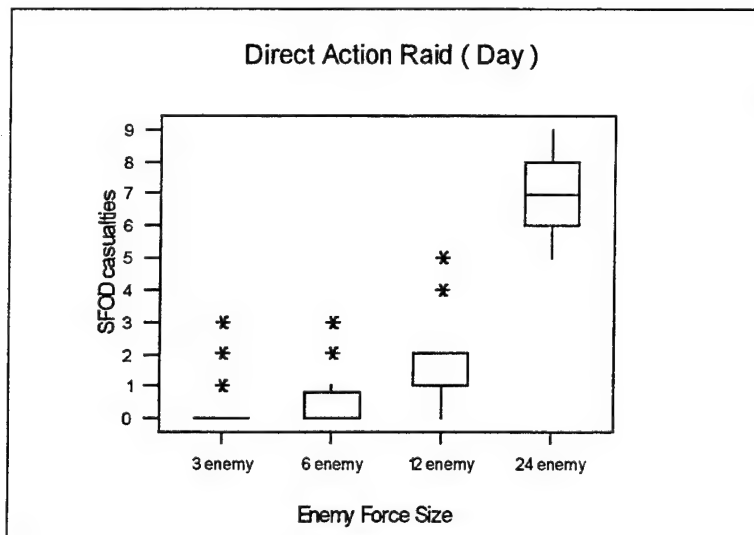

Figure 4-1. Direct Action Raid Casualties (Day)

The SFOD suffered zero casualties for all replications of the night raid against six enemy forces on the objective, so it is assumed that the detachment would suffer zero attrition during a night raid against three enemy. The detachment's average number of casualties during the night scenario increases from 0 to .35, and 2.15 respectively. The median number of casualties, is zero against six and twelve enemy and increases to two against twenty-four enemy. There are no outside values in the casualty distribution against six enemy while three appear when the enemy force size increases to twelve (see Figure 4-2).
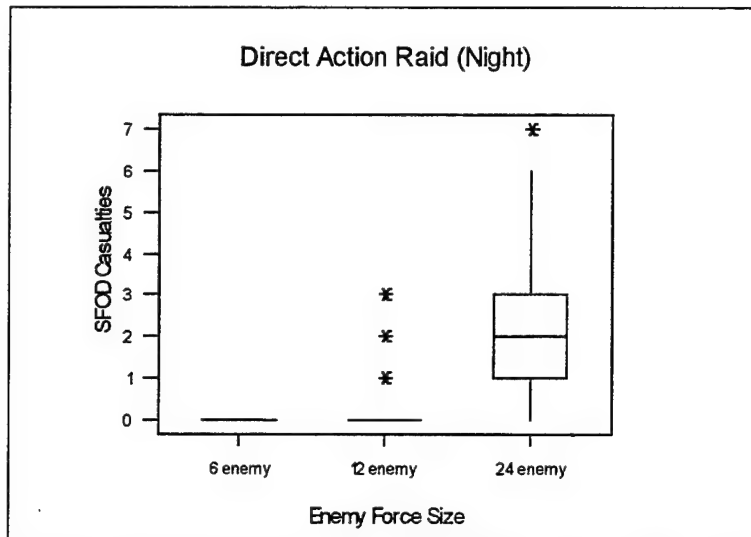
Figure 4-2. Direct Action Raid Casualties (Night)

For both day and night scenarios the interquartile range (IQR), which displays the spread of the middle half of the casualties, also increases as the enemy force size increases on the objective. This increased spread in the casualty distribution is very apparent in the boxplots of SFOD casualties against twenty-four enemy. These boxplots are also more normally distributed than the other boxplots.

a. Break Contact

The distribution of casualties suffered during the break contact force-on-force engagement demonstrates similar trends to those discussed above. The average number of casualties increases from .15, to .75, 3.55 and 4.15 respectively. The SFOD casualty IQR increases as the enemy force size on the objective increases from three to twelve soldiers. The SFOD casualty IQR then reduces its spread against twenty-four enemy. Again, the outside values in the boxplot of casualties against three enemy appear because all but two replications resulted in zero SFOD casualties. The largest increase in detachment casualties clearly occurs when the enemy force size increases from six to twelve soldiers. The distribution of casualties also appear to be distributed more normally as the enemy force size increases (see Figure 4-3).
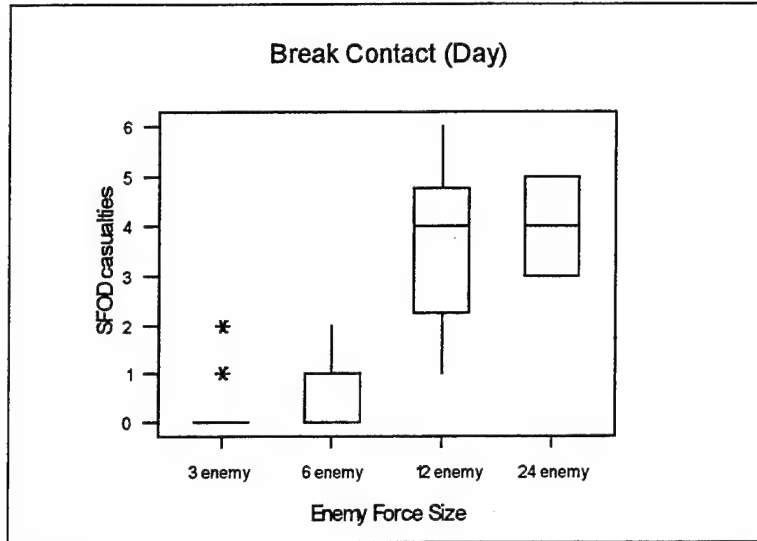
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Figure 4-3. Break Contact Casualties (Day)

All night break contact scenario replications resulted in zero attrition to the SFOD. The detachment was able to detect the enemy with the aid of the night vision devices and successfully move back into the woodline prior to detection by enemy forces. With no night vision capabilities, the enemy had little chance of detecting and engaging the detachment.

2. Illumination Conditions

The boxplots of the day and night raid clearly reveal a reduction in detachment casualties during night versus day force-on-force engagements (see Figures 4-1 and 4-2). As expected, a force with night vision capabilities has a distinct advantage over a force lacking this capability. Special operations forces can greatly reduce their chance of casualties by exploiting this advantage and conducting operations during periods of limited visibility.

3. Direct Action versus Break Contact

There is no apparent difference in the number of SFOD casualties suffered in the direct action versus the break contact force-on-force engagement against three and six enemy. However, there is a noticeable difference in the SFOD casualty boxplots against twelve and twenty-four enemy (see Figures 4-1 and 4-3). The SFOD casualties during the

raid remain low against twelve enemy and sharply increase against twenty-four enemy while the break contact casualties increase in a more linear fashion.

The SFOD casualties during the raid scenario are greatly influenced by the number of enemy forces surviving prior to the assault force moving across the objective. As the enemy force surviving prior to the assault increases, the number of SFOD casualties also increase. The majority of enemy forces are destroyed prior to the assault against three, six, and twelve enemy resulting in low attrition to the SFOD. However, a sizable enemy force survives prior to the assault in the raid against twenty-four enemy resulting in a sharp increase in SFOD casualties.

During the break contact scenario the SFOD is generally more exposed to enemy fire throughout the duration of the force-on-force engagement. However, the SFOD is able to maintain a relatively fixed distance between itself and the enemy forces as it moves back into the woodline. This results in a nearly steady increase in the SFOD casualties during the break contact force-on-force engagement.

C. CASUALTIES AS A FUNCTION OF TIME

In order to calculate accurate MLE's for the attrition coefficients, it is important to examine the behavior of battle casualties with respect to time. To capture casualty trends with respect to time, the casualty times for the replicated scenarios were aggregated, sorted in ascending order and cumulatively plotted as a function of casualty times. Initial calculations of MLEs of attrition coefficients revealed that force-on-force engagements with linear casualty plots produced fairly accurate attrition coefficient estimates while force-on-force engagements with nonlinear casualty plots produced less precise estimates. This discovery revealed a need to break some force-on-force engagements into phases to increase the accuracy of the attrition coefficient estimates. General casualty trends with respect to the raid and break contact scenarios are discussed below.

1. Direct Action Raid

The casualty versus time plot for the day raid force-on-force engagement, displayed below in Figure 4-4, shows a rapid increase in enemy casualties with very few casualties suffered by the detachment during the first thirteen minutes of the engagement. However, after this point in time the casualty rate for the SFOD increases while the enemy's casualty rate decreases.
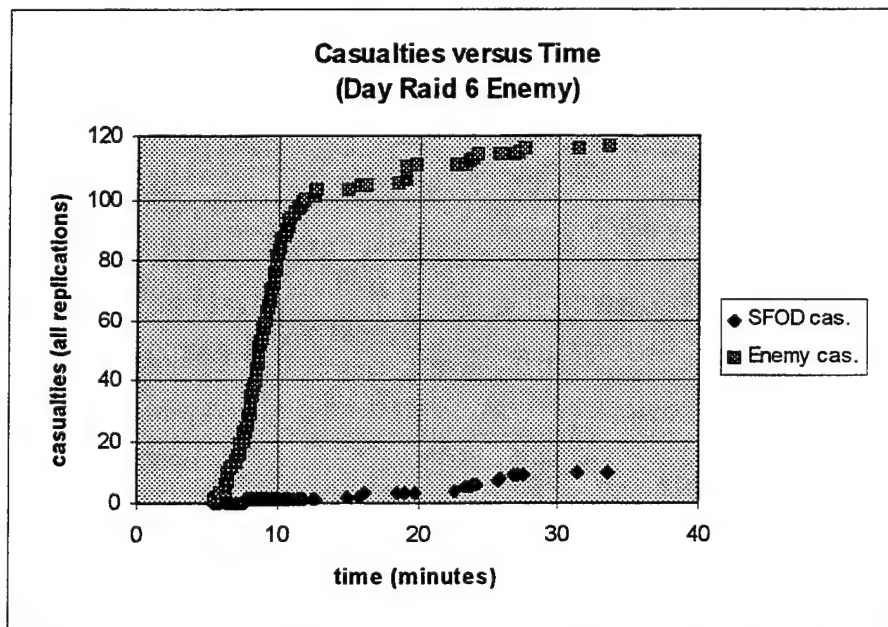

Figure 4-4. Day Raid Casualty versus Time Plot (6 Enemy)

It is easy to see that partitioning this engagement at thirteen minutes produces four near linear casualty versus time plots. The need to partition this battle is also easily explained in a tactical sense. During the initial phase of the engagement a heavy volume of fire from the detachment's support positions steadily attrits the enemy forces. Detachment members are generally concealed and less exposed to enemy fire during this phase of the engagement. During the second phase, the assault element closes and sweeps across the objective. Enemy forces surviving the initial phase now become a hazard to the exposed assaulting forces. For the purpose of this study, phase I of the raid, the support phase, will be the force-on-force engagement prior to thirteen minutes and phase II, the assault phase, will refer to the remainder of the engagement.

The trend, displayed in the graph, is consistent for most day direct action scenarios. The most noticeable deviation is seen in the casualty versus time plot for twenty-four enemy (see Figure 4-5). This plot reveals a steady increase in detachment casualties during both phases of the engagement. However, the most noticeable change is the drastic increase in SFOD casualties after thirteen minutes into the engagement.
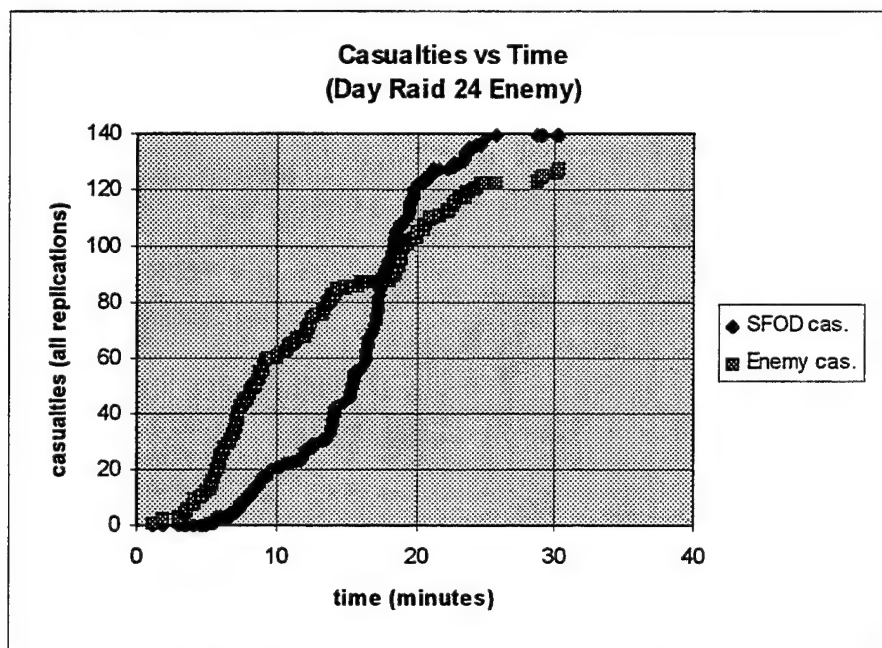

Figure 4-5. Day Raid Casualty versus Time Plot (24 Enemy)

This is due to the increased number of enemy who survive the first phase of the raid and remain on the objective during assault phase.

The night raid scenarios casualty versus time plot results in a fairly linear casualty trend for both the SFOD and the enemy forces (see Figure 4-6). This is likely a result of the fact that all weapons are less accurate under night firing conditions. The support elements, which proved to be extremely lethal during the day assault, lose some of their accuracy. However, the lethality of the assault force is greatly increased. As the assault force closes on the objective it is able to acquire and engage enemy forces prior to being detected with the aid of the night vision devices.
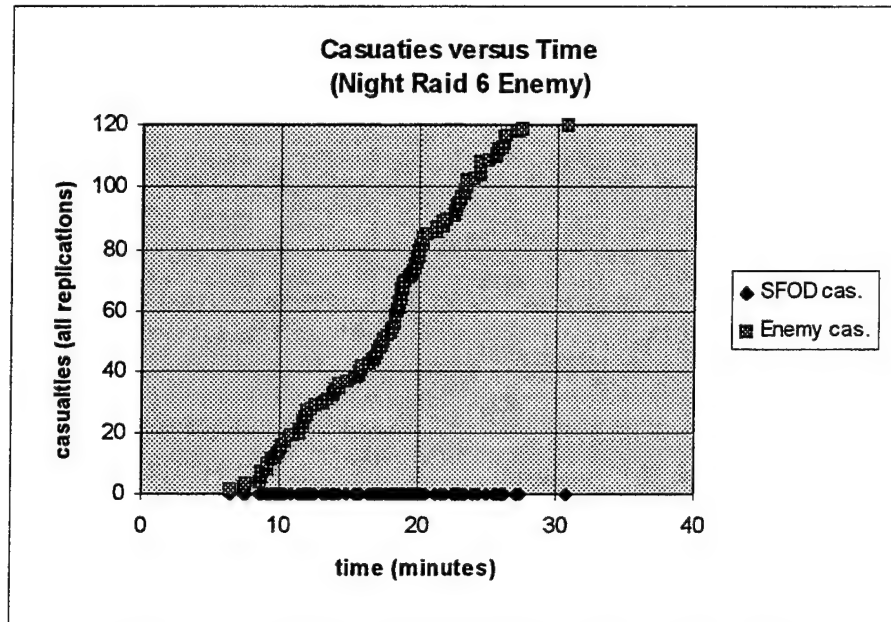
Casuaties versus Time
(Night Raid 6 Enemy)

casualties (all replications)

120
100
80
60
40
20
0

◆ SFOD cas.
▦ Enemy cas.

0   10   20   30   40
time (minutes)

Figure 4-6. Night Raid Casualty versus Time Plot

The increased effectiveness of the SFOD in phase II becomes more evident as the enemy force size on the objective increases. See the night raid casualty versus time plot against twenty-four enemy (see Figure 4-7).
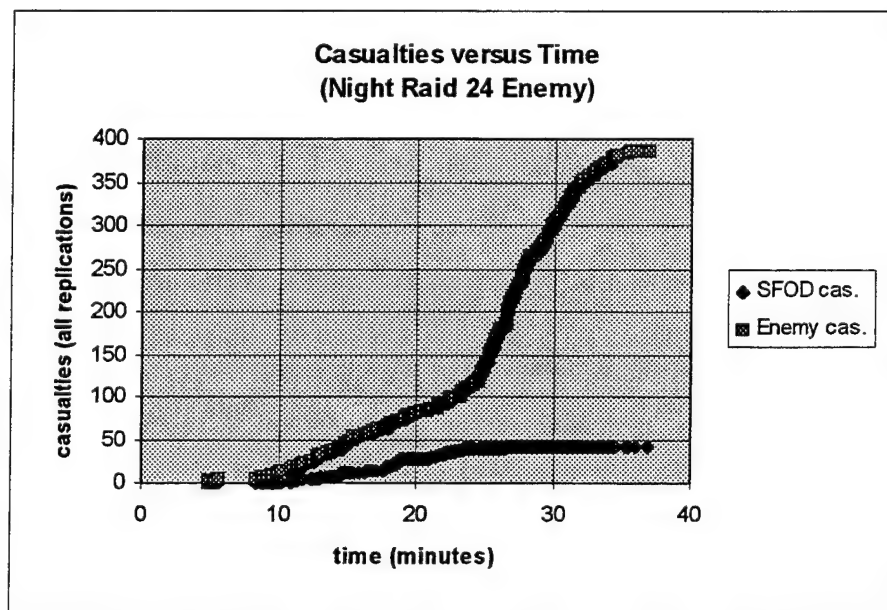
Casualties versus Time
(Night Raid 24 Enemy)

casualties (all replications)

400
350
300
250
200
150
100
50
0

◆ SFOD cas.
▦ Enemy cas.

0   10   20   30   40
time (minutes)

Figure 4-7. Night Raid Casualty versus Time Plot

The enemy casualties clearly increase in the assault or second phase of the engagement causing a nonlinear enemy cumulative casualty plot. However, the

detachment's cumulative casualty plot remains fairly linear, and there is no need to partition the night raid engagement into phases to produce accurate attrition coefficient estimates.

2. Break Contact

The casualty versus time plot for the day break contact shows a fairly linear cumulative casualty plot for both forces in all scenarios (see Figure 4-8). Since both forces are primarily exposed during the engagement, casualties seem to occur at a relatively steady rate.
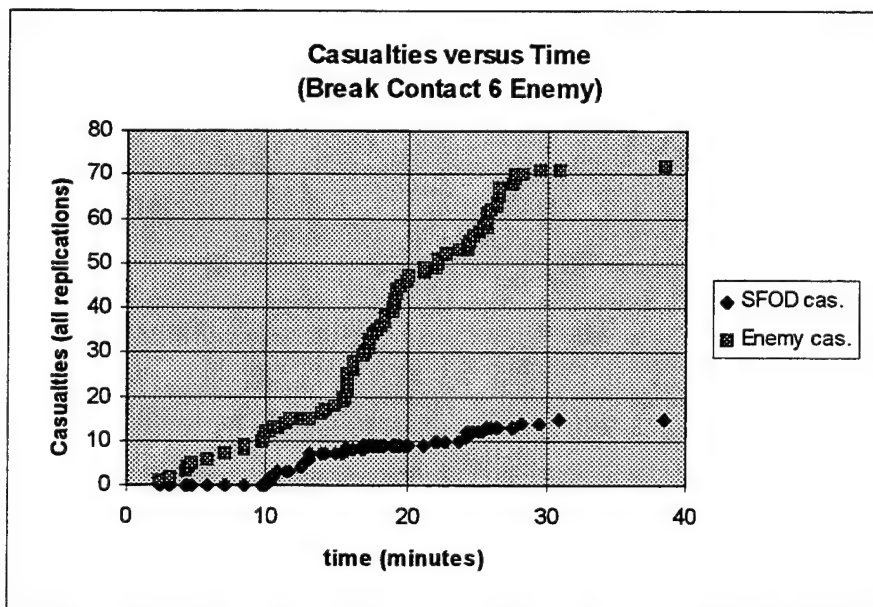
Casualties versus Time
(Break Contact 6 Enemy)

Figure 4-8. Day Break Contact Casualty versus Time Plot

The most noticeable departure from this trend is seen in the casualty versus time plot against twenty-four enemy (see Figure 4-9). A larger initial enemy force size results in a larger enemy force that survives and closes on the detachment withdrawing into the woodline. As the enemy force closes it is subject to increasingly accurate fire from the detachment's overwatch positions, causing the noticeable increase in enemy casualties after fifteen minutes into the engagement. Again, the detachment's cumulative casualty plot remains fairly linear, and there is no need to partition the engagement into phases.
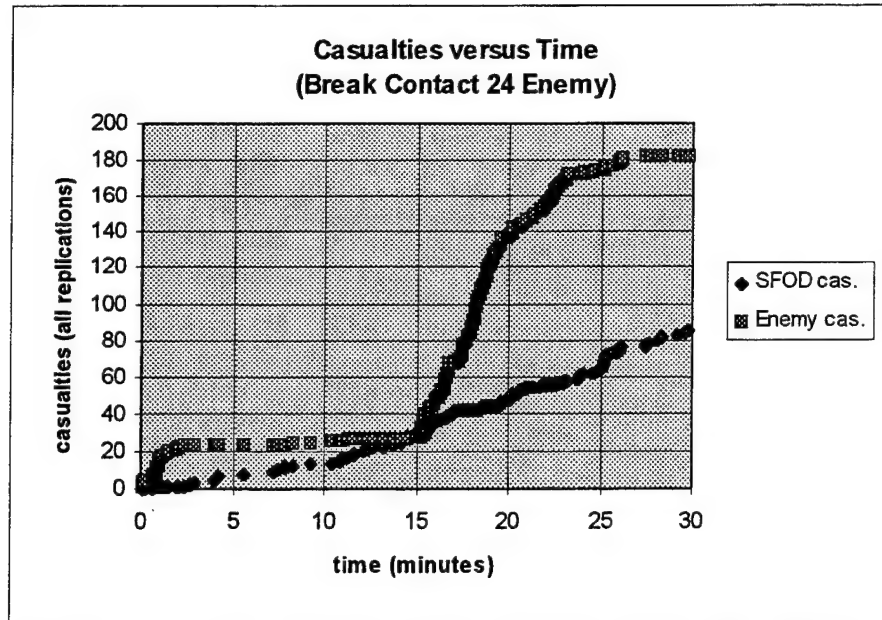
35

Figure 4-9. Day Break Contact Casualty versus Time Plot

D. MLE ATTRITION COEFFICIENTS CALCULATIONS

1. General

Maximum likelihood estimates of attrition coefficient were calculated for each force-on-force scenario simulation replication. The time series of casualties from each Janus simulation replication was input into a spread sheet. The time series of casualties for each replication was sorted in ascending order and the attrition coefficient MLEs were calculated using equation (2).

2. MLE Accuracy

The accuracy of each simulation replication's attrition coefficient MLE was checked by using the Lanchester equation for aimed fire. This was accomplished by substituting the MLEs and the replication's simulation time into the Lanchester equation, equation (1), and calculating the predicted number of casualties to each side. The results were then compared to the actual simulation casualties to check the accuracy of the predicted results.

Initial MLE calculations for the direct action raid provided accurate casualty predictions for the enemy but over estimated the SFOD casualties. Utilizing the insight gained through the casualty versus time plot the engagement was partitioned into two

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phases which greatly improved the accuracy of the MLEs. The accuracy of attrition coefficient MLEs clearly improve as the time interval it is calculated over decreases. However, partitioning the force-on-force engagement into many small time intervals greatly increases the effort of calculating MLEs and also increases the complexity of casualty decision trees. The goal of this study is to calculate SFOD attrition coefficient MLEs that predict casualties within approximately one casualty of the simulation result.

3. MLE Probability Distributions

Attrition coefficient MLEs were fit to theoretical probability distributions in an effort to capture the overall behavior of the parameters. Knowing the attrition coefficient estimate's probability distribution enables the standard Lanchester equations to capture some of the stochastic nature of the high resolution model results. If desired, this can be accomplished by treating the attrition coefficient as a random variable in the Lanchester equation. Due to the limited samples taken in this study fitting attrition coefficient MLEs to theoretical probability distributions was not possible for all the scenarios modeled. However, probability distributions were fit to scenarios that contained more than seven non-zero attrition coefficient estimates. If the scenario failed to yield seven non-zero attrition coefficients estimates, the average values were utilized as the parameters in the casualty outcome trees. All mean and standard deviation calculations displayed in the tables utilize the non-zero observations. This results in parameter calculations that are conditioned on the fact that casualties have occurred. The Anderson-Darling normality test [Ref. 9] was utilized to determine if the normal distribution was appropriate for the attrition coefficient estimates sampled. The null hypothesis of the test is that the attrition coefficient estimates are normally distributed. The test was performed at a significance level of 0.05. Thus if the attrition coefficient estimates' p-value is strictly less than 0.05 the null hypothesis is rejected.

Only one attrition coefficient MLE was determined to be an outlier. This attrition coefficient estimate was calculated for phase I of the day raid against twenty-four enemy. Examining the normal probability plot, Figure 4-10 below, the outlier of 0.024 is clearly

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revealed. The remainder of the observations appear to be fairly symmetric and tightly grouped between 0.0035 and 0.0115.
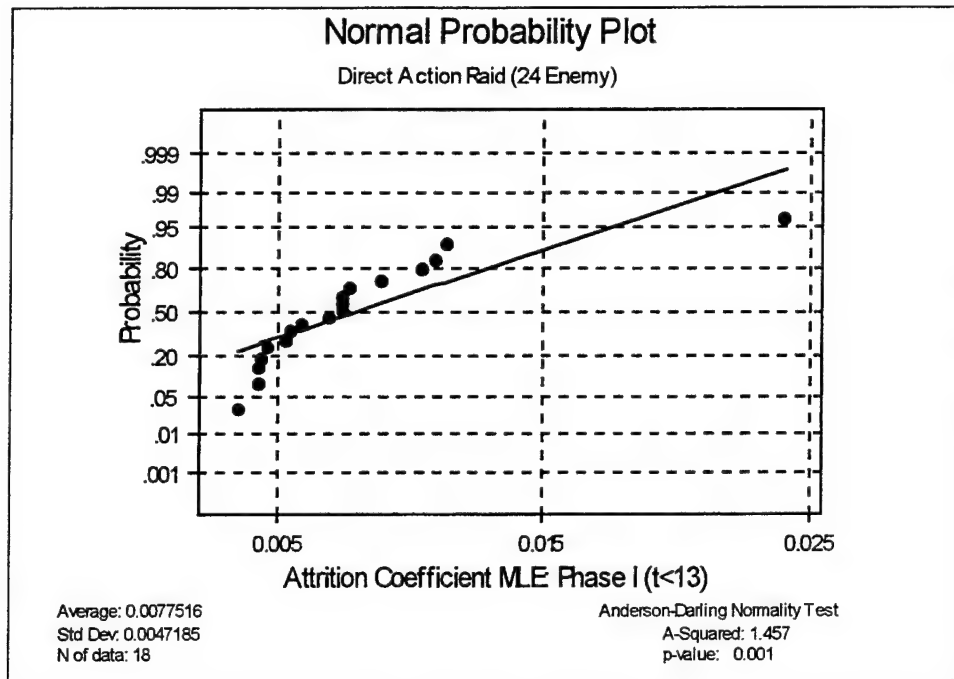

Figure 4-10. Direct Action Raid Normal Probability Plot (24 Enemy)

Examining the results of the raid replication that produced this MLE revealed that the detachment suffered an unprecedented six casualties during phase I of the simulation. The highest number of casualties suffered during phase I of the remaining nineteen replications was three with an average number of casualties of 1.42. The extremely high number of casualties suffered during phase I of this replication is clearly an unlikely event and was removed from the probability plot. The samples were plotted again without the outlier, see Figure 4-11, and they clearly become more symmetric and normally distributed. The p-value for the Anderson-Darling normality test increases from 0.001, a rejection of the null hypothesis, to 0.239 which allows for acceptance of the null hypothesis.
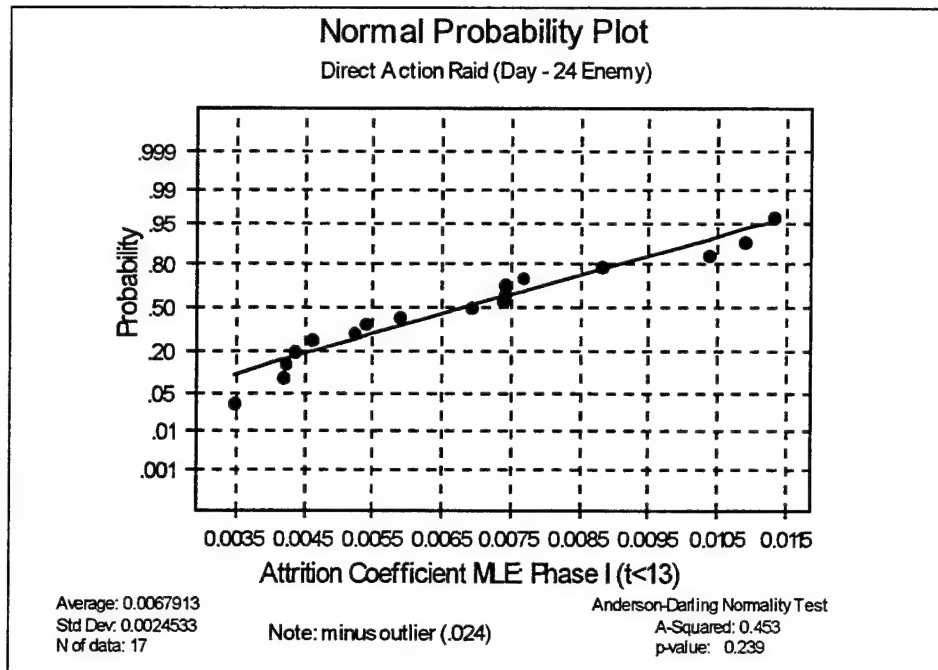
38

Figure 4-11. Direct Action Raid Normal Probability Plot (24 Enemy)

The majority of the Anderson-Darling normality tests for the attrition coefficient estimate samples failed to reject the null hypothesis. However, some of the p-values were close to the significance level. After studying the data, the author feels that this is primarily due to the relatively small sizes of the samples tested in this study. Larger sample would likely produce higher p-values, resulting in increased confidence that the distributions are nearly normal. Samples for which the null hypothesis was rejected were fit to the Wiebull distribution. The Wiebull distribution has a shape and scale parameter that enables it to better fit probability distributions that are not symmetric in the tails. The graphs of all Anderson-Darling normality tests can be found in Appendix C.

E. SFOD CASUALTY OUTCOME TREES

The purpose of developing casualty outcome trees is to provide a model for incorporating the attrition coefficients developed in this study into aggregate combat models that resolves combat casualties using Lanchester equations. General casualty outcome trees are developed for both the direct action raid and the break contact force-on-force engagements. Tables for each scenario outline the specific parameters portrayed

in the casualty outcome trees. Tables also display the p-value for all Anderson-Darling normality tests.

1. General Casualty Outcome Tree Structure

All casualty outcome trees begin with a binomial outcome which determine if the special forces detachment suffered casualties during the force-on-force engagement. Binomial outcomes are represented on the casualty outcome tree by circles. The probability of kill, P_k, represents the probability that the engagement results in a casualty to the detachment. The value of P_k was calculated by dividing the number of simulation replications that resulted in a casualty to the detachment by the total number of simulation replications. In the simple casualty outcome tree, if the binomial outcome results in a success then casualties are assessed against the detachment utilizing the attrition coefficient developed for that particular scenario. If the binomial outcome is a failure then no casualties are assessed against the detachment. Casualty assessment is represented on the tree with a diamond and is accomplished utilizing the Lanchester equation for aimed fire. Instructions on casualty assessment vary with the structure of the casualty outcome tree and will be explained below. Force-on-force engagements that are divided into phases result in more complex casualty outcome trees that utilize conditional probabilities to determine casualty results.

2. Direct Action Raid

The direct action raid resulted in two different casualty outcome trees, one for day and one for night illumination conditions. The day direct action raid casualty tree has one binomial and one probabilistic outcome. The first circle, labeled K in Figure 4-12, determines if the engagement results in casualties to the detachment. The second circle, a conditional multinomial outcome labeled P, determines which phases of the raid result in casualties. Given that casualties occur, it determines if casualties are to be assessed during only phase I, during only phase II or during both phase I and phase II of the raid.
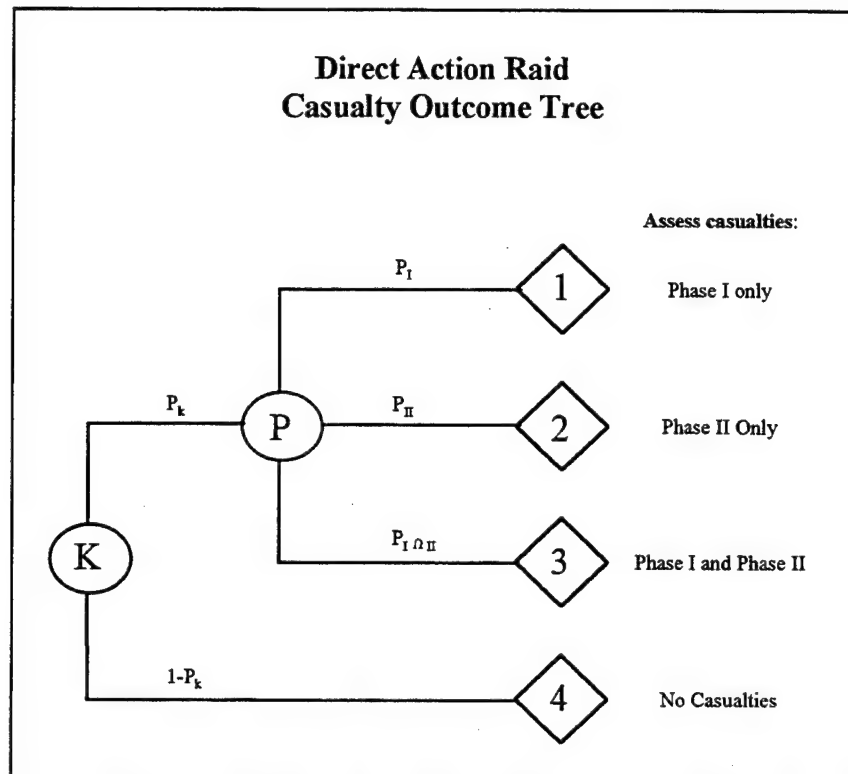
40

Figure 4-12. Day Raid Casualty Outcome Tree

The parameters depicted on the casualty outcome tree are defined as follows. P_I is the conditional probability that given the raid results in casualties, the casualties occur only in phase I. P_{II} is the conditional probability that given the raid results in casualties, the casualties occur only in phase II. $P_{I \cap II}$ is the conditional probability that given the raid results in casualties, the casualties occur in both phase I and phase II. The parameter values for all casualty outcome trees were determined directly from the Janus simulation results.

The casualty tree depicts four possible results. The multinomial outcome will determine which result leaf on the tree will be utilized to assess SFOD casualties. Given that the outcome results in leaf 1 or 2 the parameters located in Table 4-1 can be substituted into the Lanchester equation to determine the losses to the SFOD. This results in a straight forward calculation utilizing the attrition coefficient, enemy force size and the mean engagement time. If the multinomial outcome result in leaf 3, enemy casualties must also be assessed during phase I of the engagement so that the reduced enemy force size

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can be used in the phase II Lanchester calculation. Failure to adjust the enemy force level after phase I is equivalent to reconstituting the enemy force to full strength prior to the assault phase. This can be accomplished by subtracting the average number of casualties inflicted to the enemy force during phase I of the engagement from the starting enemy force size prior to calculating the SFOD losses for phase II. Both phase I and phase II SFOD casualty calculations are determined using equation (1).

The parameters values for the day raid scenario casualty tree are shown below in Table 4-1. This table and the remaining tables in this chapter provide the necessary data needed to use the casualty outcome trees and equation (1) to assess SFOD casualties. The table below displays the probabilities for both the binomial and multinomial events on the casualty outcome tree and the theoretical probability distribution used to describe the dispersion of the scenario's attrition coefficient estimates. The enemy force size and other parameters needed to assess SFOD casualties with equation (1) are also provided. They include the scenario attrition coefficient estimate mean ($\hat{a}$) and the average time in minutes of the force-on-force engagement (dt) by phase. Additional information provided are the attrition coefficient estimate standard deviation and the p-value of all Anderson-Darling normality tests. The Wiebull distribution shape and scale parameters are provided for scenarios with p-values less than 0.05.

Enemy Force Size	P_k	Phase	P_I	P_{II}	$P_{I \cap II}$	Attrition Coefficient Distribution	Mean $\hat{a}$	Standard Deviation	dt	P-Value
3	3/20	Phase I	0			N/A	.031729	0	10.49481	N/A
		Phase II		2/3	1/3	N/A	.069159	.000391	14.49964	N/A
6	1/4	Phase I	0			N/A	.018501	0	9.78333	N/A
		Phase II		4/5	1/5	N/A	.099424	.041146	16.35	N/A
12	4/5	Phase I	0			Normal	.0104583	.0011618	9.8333	.432
		Phase II		9/16	7/16	Normal	.0452738	.0219127	19.5748	.281
24	1	Phase I	0			Normal	.0067913	.0024533	10.3618	.239
		Phase II		1/10	9/10	Normal	.0247799	.0102755	12.2108	.118

Table 4-1. Day Raid Casualty Outcome Tree Parameters

The night direct action raid casualty tree has only one binomial outcome prior to determining the number of detachment casualties to assess (see Figure 4-13). Since the engagement was not partitioned into phases, the only probabilistic event is to determine, using P_k, if casualties are to be assessed against the detachment.
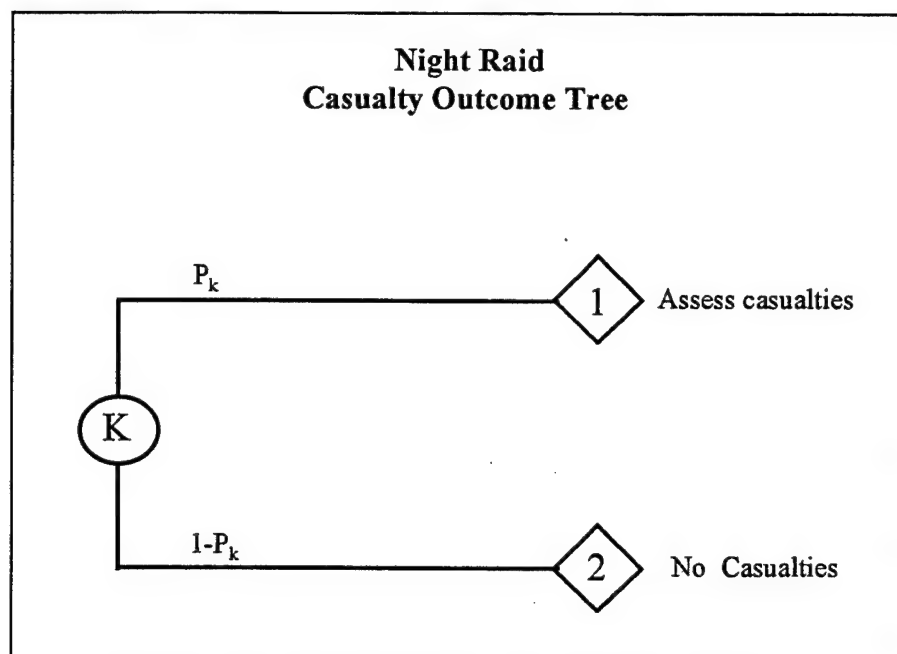

Figure 4-13. Night Raid Casualty Outcome Tree

Given that casualties are to be assessed, the parameters in Table 4-2 can be used in the Lanchester equation to determine the number of SFOD casualties.

Enemy Force Size	P_k	Attrition Coefficient Distribution	Mean $\hat{a}$	Standard Deviation	dt	P-Value
3	0	N/A	N/A	N/A	N/A	N/A
6	0	N/A	N/A	N/A	N/A	N/A
12	1/4	N/A	.007069	.002353	25.72333	N/A
24	4/5	Wiebull	.004332 Shape: 1.600146	.003032 Scale: .0048741	32.16458	N/A

Table 4-2. Night Raid Casualty Outcome Tree Parameters

3. Break Contact

The break contact casualty outcome tree has the same structure as the night raid casualty outcome tree depicted in Figure 4-13 above. Since the break contact force-on-force engagement was not partitioned into phases it requires only a binomial outcome to determine if casualties are to be assessed. Given that binomial outcome determines that casualties are to be assessed, the parameters in Table 4-3 can be used in the Lanchester equation to determine the number of SFOD casualties.

Enemy Force Size	P_k	Attrition Coefficient Distribution	Mean $\hat{a}$	Standard Deviation	dt	P-Value
3	1/10	N/A	.019914	.011294	30.32	N/A
6	11/20	Wiebull	.011663 Shape: 2.07762	.006345 Scale: .00132589	24.58	.02
12	1	Normal	.0084685	.002867	27.48	.124
24	1	Normal	.0080383	.0016541	25.81	.642

Table 4-3. Break Contact Raid Casualty Outcome Tree Parameters

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Special operations forces are employed across the entire spectrum of conflict and serve as a strategic asset that cannot be built-up quickly or easily replaced when lost. Anticipating combat attrition to special operations forces is critical to USSOCOM in maintaining the proper force level to meet the expanding role of SOF in peacetime and in war. High resolution models such as Janus can be used as a tool to model and develop SOF attrition coefficients. Attrition coefficients developed from high resolution combat models can be used in aggregate combat models that resolve attrition using Lanchester equations.

The SOF scenarios modeled in this study are well suited for developing attrition coefficients using the MLE attrition coefficient technique. The scenarios modeled involve direct force-on-force engagements between special operations forces and enemy forces. The high resolution combat model used in this study produced a time series of casualties for each simulation replication. The short duration of the force-on-force engagements modeled make them ideal for producing MLE attrition coefficient estimates. Assessing the distribution pattern of MLEs provides added insight into the overall behavior of the attrition coefficient estimates.

The casualty outcome trees developed for the scenarios capture the overall pattern of SOF attrition resulting from the high resolution model simulation replications. The attrition coefficient estimates developed in this study are conditional in nature and rely on binomial and probabilistic outcomes to determine when they are to be used in Lanchester equations to assess casualties. Casualty outcome trees are simple in structure and could easily be incorporated into aggregate combat models to resolve SOF attrition.

The diverse role of special operations forces in peacetime and in war makes it particularly difficult to predict all situations in which SOF casualties can occur in a conflict. Special operations forces are often employed in strategic economy of force operations where direct contact with enemy forces is unlikely. While, other SOF missions place soldiers in situations where direct contact with enemy forces is inherent or very

probable. The direct action raid and special reconnaissance mission are clearly two situations in which force-on-force engagements with enemy forces may occur. Larger scale operations like those conducted by ranger units are also well suited for modeling and developing attrition coefficients with high resolution models.

However, attrition to special operations forces is not always a process that can be modeled using Lanchester models of warfare. Employment of SOF onto the modern non-linear battlefield will result in situations where massive casualties will be suffered to the force in a small instance of time. Examples of such situations are SO aircraft that are shoot down on infiltration/exfiltration or SO detachments that are compromised and engaged by enemy aircraft or artillery. These situations produce multiple casualties at the same time and are ill-suited for portrayal with Lanchester models. They are also likely to be SOF's greatest casualty threat in future conflict.

The attrition coefficients developed in this study are only as good as the high resolution model and the item level data input into the model. Accurately modeling special operation forces in a high resolution model is a difficult task. However, as high resolution models evolve, their ability to model special operations forces should continue to improve. Current efforts in modeling dismounted soldiers look promising and should enhance the efforts of future studies.

B. RECOMMENDATIONS

The following recommendations are made for future studies involving modeling and developing attrition factors for special operations forces.

A study needs to be conducted to quantify the difference in marksmanship skills between a conventional soldier and a SOF soldier. This will ensure an accurate adjustment of the $P_{h|s}$ tables in high resolution models to better represent the lethality of special operations forces. This study used a ten percent increase which is likely to be a conservative estimate.

Future studies could provide additional insight into SOF attrition by varying additional model parameters in the scenarios. Variations could be made to the size of the special operations force and the its weapons. Enemy forces in the scenarios could be

refined with different weapons and night vision capabilities. Future SOF weapons could be tested in scenarios to see if they enhance the survivability of SO forces when compared to current weapons. Scenarios could also be modeled in various terrain and illumination conditions.

Developing and maintaining a robust library of SOF attrition coefficients will require an extensive high resolution modeling effort by USSOCOM. Attrition coefficients could be developed for particular major regional conflicts and contingency operations. However, the attrition coefficients would need to be periodically updated as SOF and enemy capabilities changed. The resources and effort to accomplish this would be quite extensive. Finally, in the absence of detailed historical data on SOF attrition, USSOCOM should maintain a database of casualties suffered by SO forces conducting training operations at JRTC. This would provide the command with a rough idea of casualties suffered to special operations forces in a low intensity conflict. It could also be used to verify the model results of SOF attrition studies using high resolution and aggregate combat models.

APPENDIX A. JANUS SENARIOS

The figures in this appendix graphically depict the direct action raid and break contact scenarios as represented on the Janus screen. The threat force and the SFOD were placed on the same screen so that the reader can see the initial array of forces on the Fort Polk terrain.
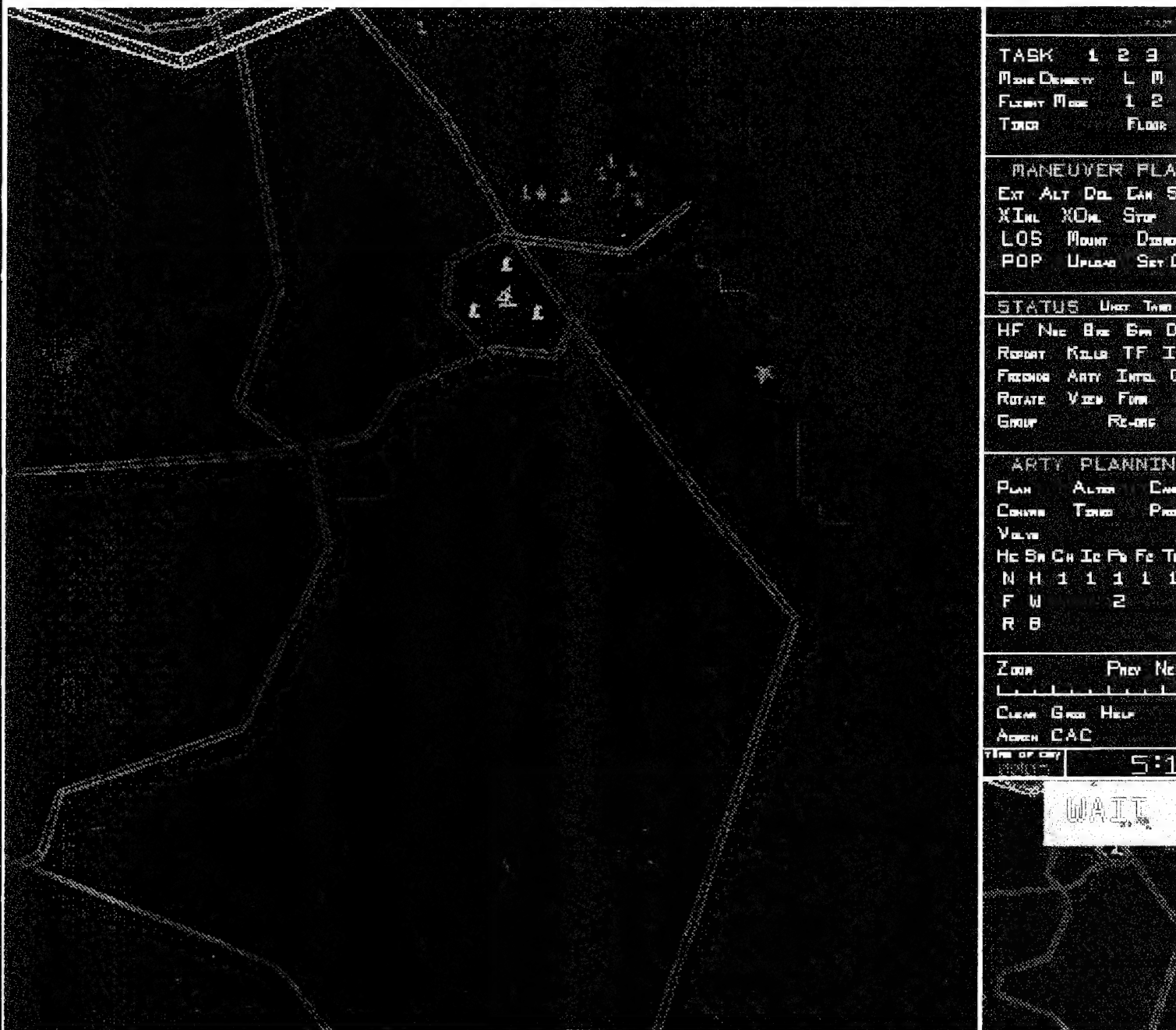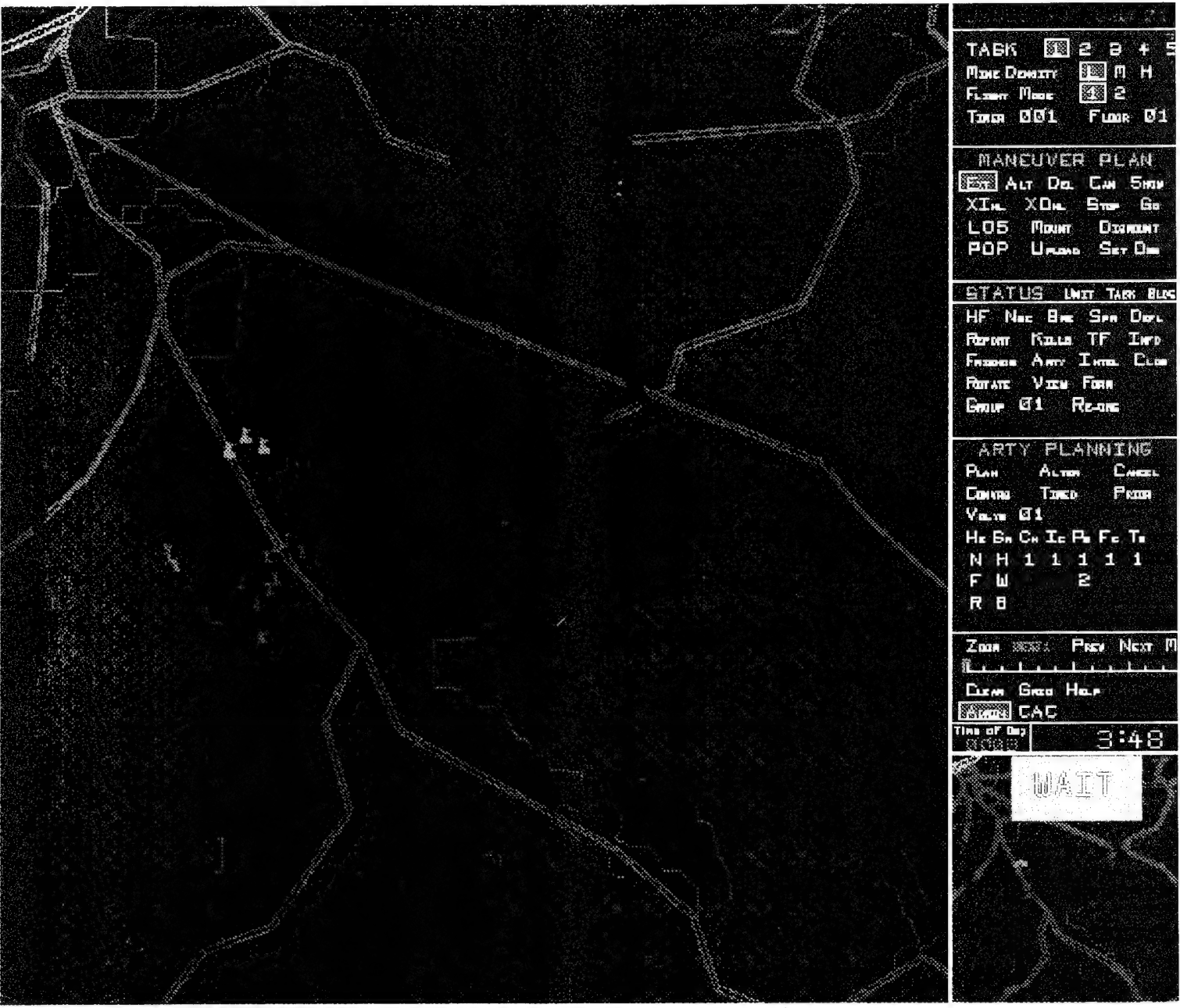
Figure A-1. Direct Action Raid Scenario

Figure A-2. Break Contact Scenario

APPENDIX B. CASUALTY VS. TIME PLOTS

The following plots are the remaining casualty versus time plots for the direct action raid and the break contact senarios.
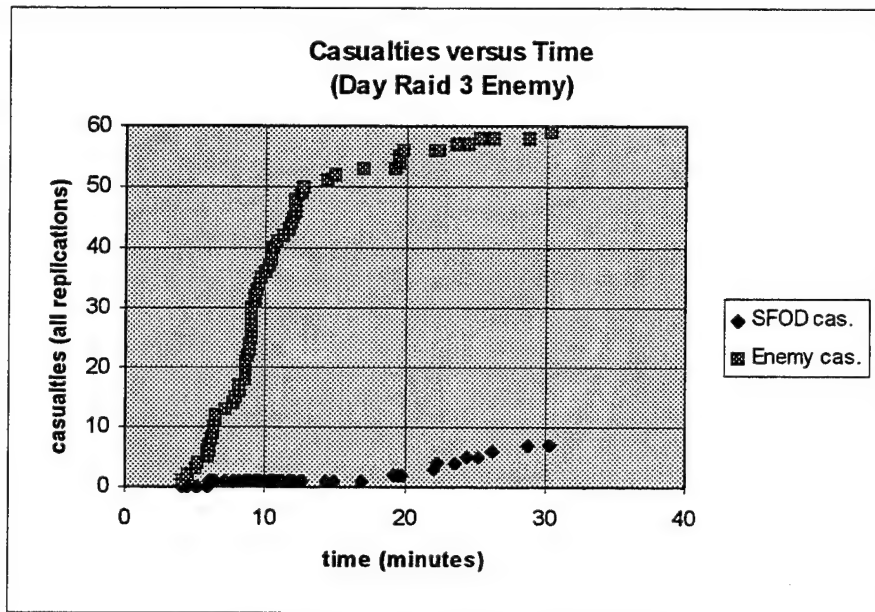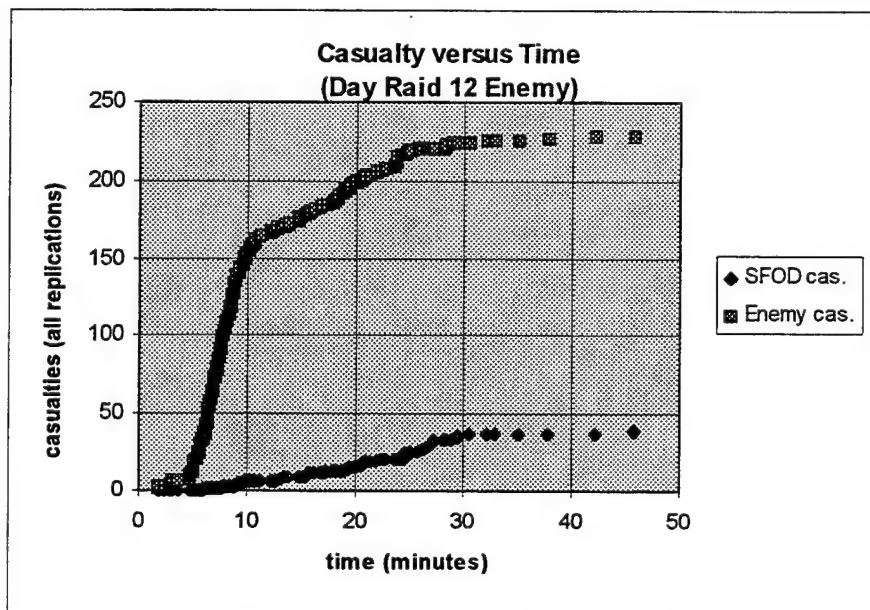

Figure B-1. Day Raid (3 Enemy)
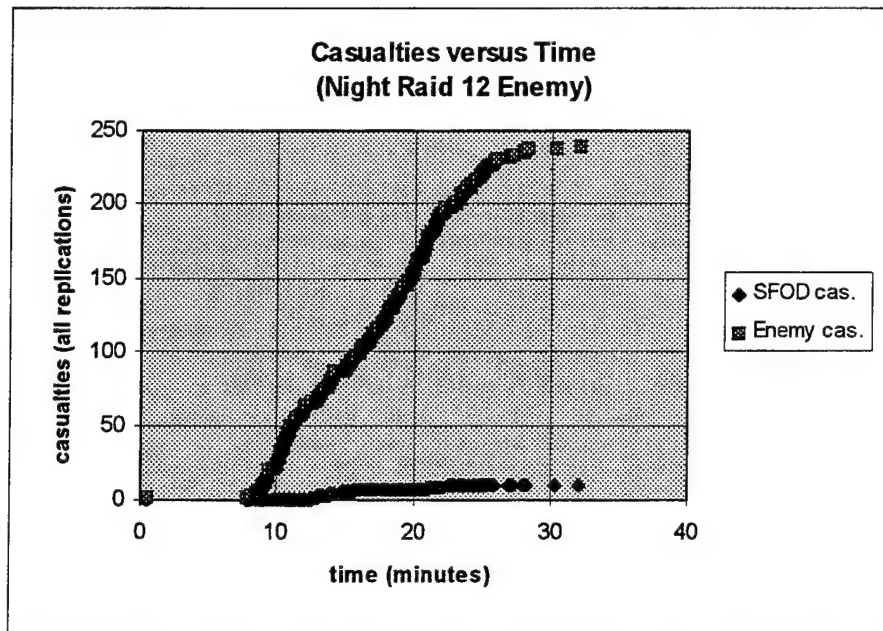

Figure B-2. Day Raid (12 Enemy)
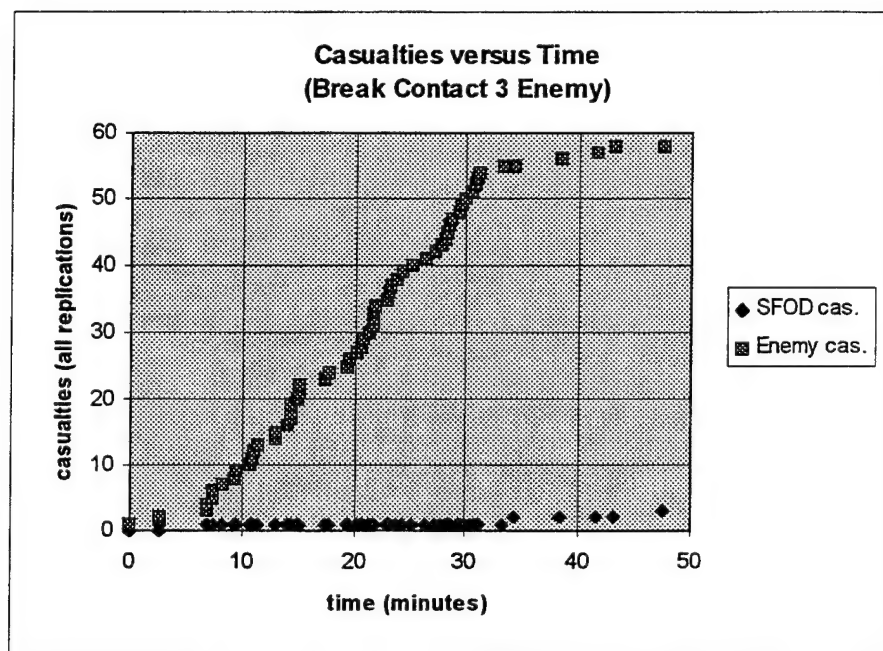
Figure B-3. Night Raid (12 Enemy)

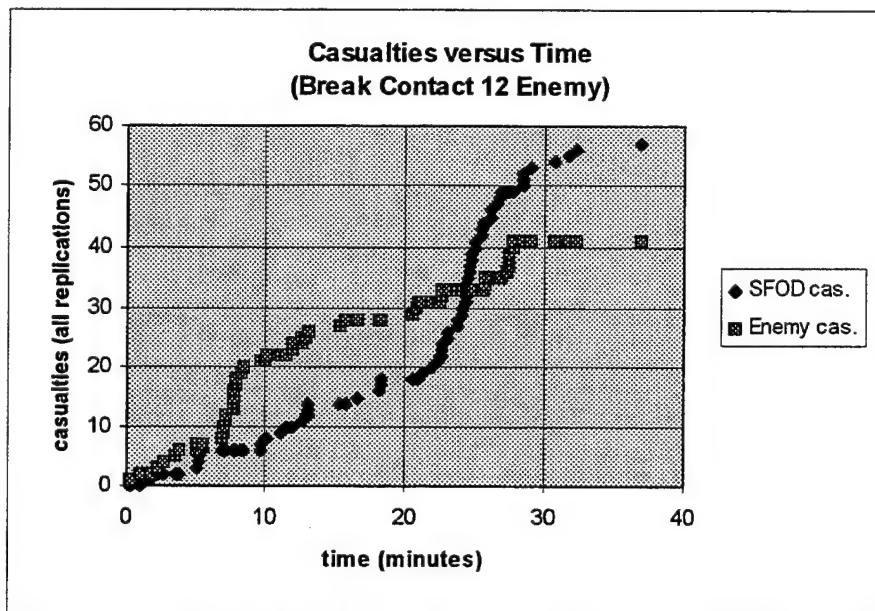**Figure B-4. Break Contact (3 Enemy)**

Figure B-5. Break Contact (12 Enemy)

APPENDIX C. RESULTS OF ANDERSON-DARLING NORMALITY TESTS

The graphs of all remaining probability plots and Anderson-Darling normality tests are contained in this appendix. The plots were conducted on all attrition coefficient samples that contained more than seven non-zero observations.
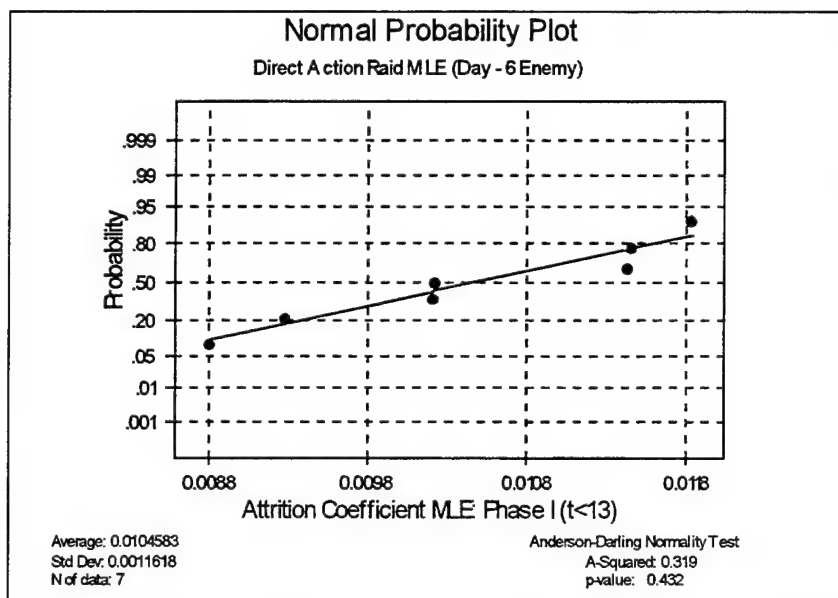

Normal Probability Plot
Direct Action Raid MLE (Day - 6 Enemy)

Attrition Coefficient MLE Phase I (t<13)

Average: 0.0104583
Std Dev: 0.0011618
N of data: 7

Anderson-Darling Normality Test
A-Squared: 0.319
p-value: 0.432

Figure C-1. Phase I: DA Raid (Day - 12 Enemy)

Normal Probability Plot
Direct Action Raid (Day - 12 Enemy)

Attrition Coefficient MLE Phase II (t>13)

Average: 0.0452738
Std Dev: 0.0219127
N of data: 16

Anderson-Darling Normality Test
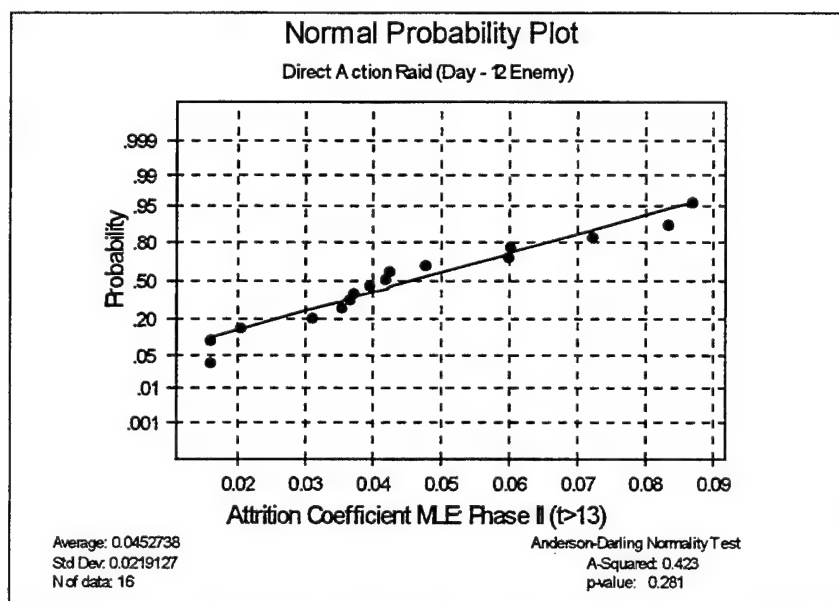A-Squared: 0.423
p-value: 0.281

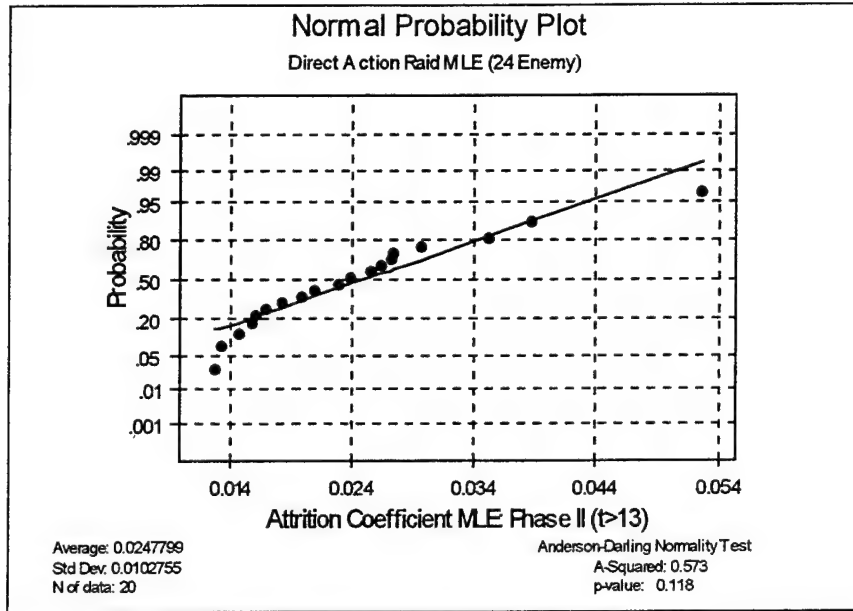**Figure C-2. Phase II: DA Raid (Day - 12 Enemy)**
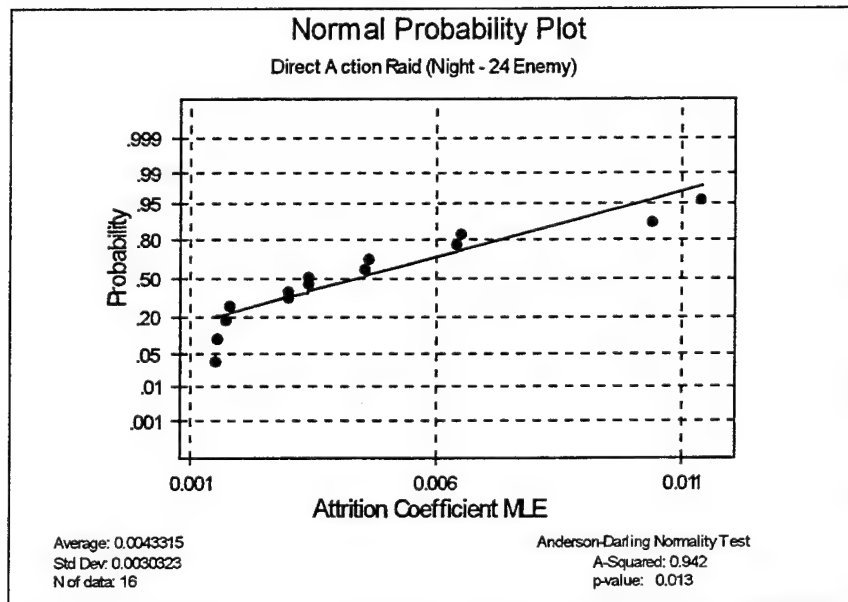
Figure C-3. DA Raid (Night - 12 Enemy)

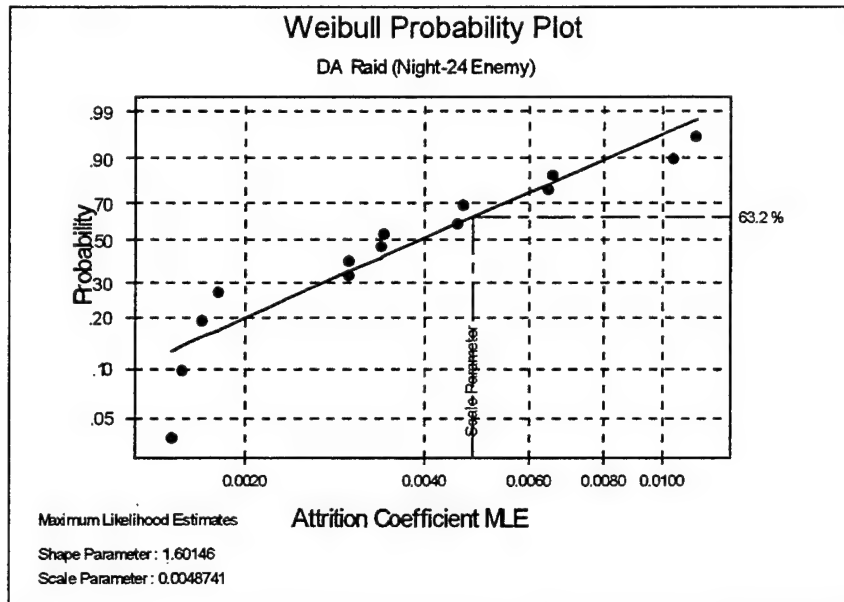**Figure C-4. DA Raid (Night - 24 Enemy)**

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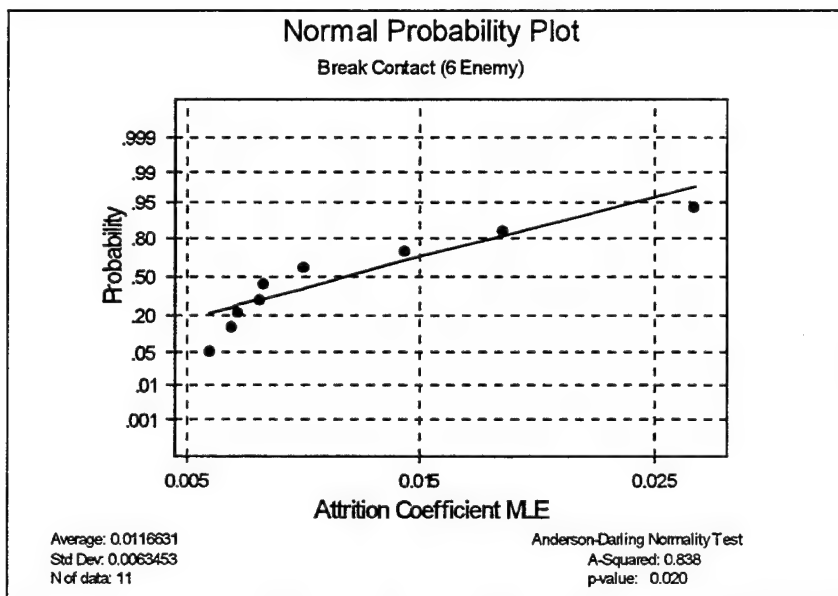**Figure C-5. DA Raid (Night - 24 Enemy)**

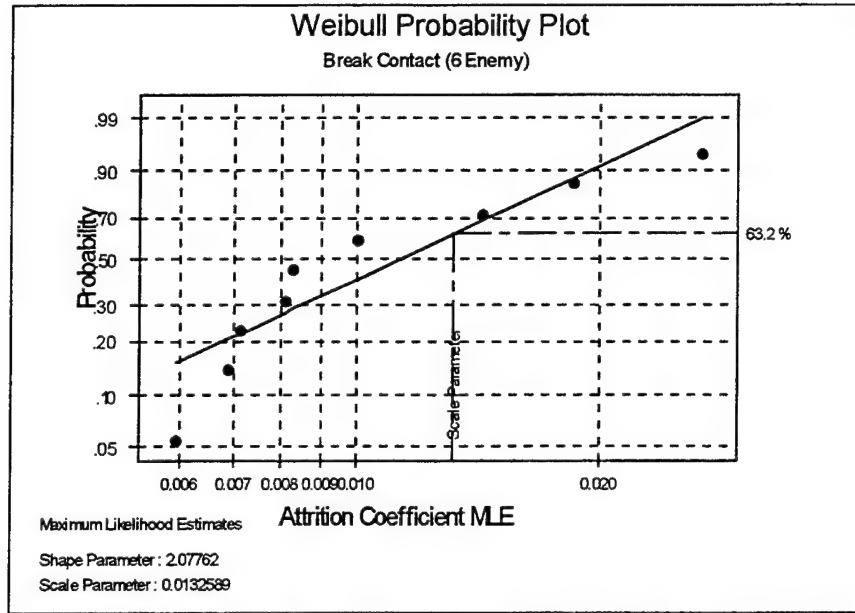**Figure C-6. Break Contact (Day - 6 Enemy)**

Figure C-7. Break Contact (Day - 6 Enemy)

Figure C-8. Break Contact (Day - 12 Enemy)

Normal Probability Plot

Break Contact (24 Enemy)

Average: 0.0080383
Std Dev: 0.0016541
N of data: 20

Anderson-Darling Normality Test
A-Squared: 0.269
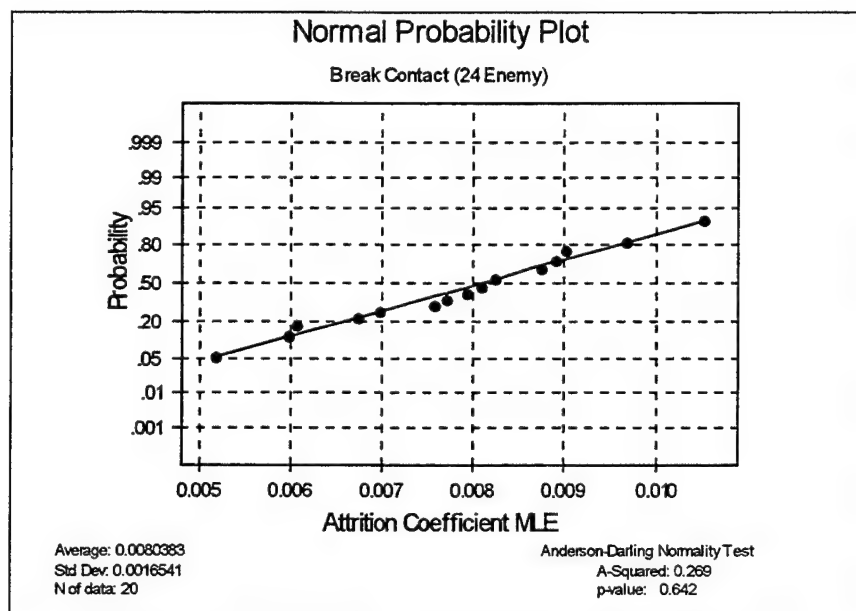p-value: 0.642

Figure C-9. Break Contact (Day - 24 Enemy)

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